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Geotechnical Analysis Report For July 2003 – June 2004

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Waste Isolation Pilot Plant

Geotechnical Analysis Report for July 2003 – June 2004
DOE/WIPP 05-3177, Vol. 1

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Foreword and Acknowledgments

This report contains an assessment of the geotechnical status of the Waste Isolation Pilot Plant (WIPP). During the excavation of the principal underground access and experimental areas, the status was reported quarterly. Since 1987, when the initial construction phase was completed, reports have been published annually. This report presents and analyzes data collected from July 1, 2003, to June 30, 2004.

This Geotechnical Analysis Report (GAR) was written to meet the needs of several audiences. This report satisfies the requirements presented in the WIPP Hazardous Waste Permit[1] and the Certification of Compliance[2] with Subparts Band C, Title 40 *Code of Federal Regulations* (CFR) Part 191, "Environmental Radiation Protection Standards for Management and Disposal of Spent Nuclear Fuel, High-Level and Transuranic Radioactive Wastes." It focuses on the geotechnical performance of the various components of the underground facility, including the shafts, shaft stations, access drifts, and waste disposal areas. The results of investigations of excavation effects and other geologic studies are also included. The report compares the geotechnical performance of the repository to the design criteria. It describes the techniques that were used to acquire the data and the performance history of the instruments. The depth and breadth of the evaluation of the different components of the underground facility vary according to the types and quantities of data available and the complexity of the recorded geotechnical responses. Graphic documentation of data and tabular documentation of instrument history can be provided upon request.

This GAR was prepared by Washington TRU Solutions LLC (WTS) for the U.S. Department of Energy (DOE), Carlsbad Field Office (CBFO), Carlsbad, New Mexico. Work was supported by the DOE under Contract No. DE-AC29-01AL66444.

[1] New Mexico Environment Department (NMED), 1999, "Waste Isolation Pilot Plant Hazardous Waste Facility Permit," NM4890139088-TSDF, Santa Fe, New Mexico
[2] Federal Register, Vol. 63, No. 95, pp. 27354, May 18, 1998

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Acronyms and Abbreviations

b.p.	before present
bsc	below shaft collar
CAO	Carlsbad Area Office
CBFO	Carlsbad Field Office
CFR	Code of Federal Regulations
CH	contact-handled
cm	centimeter(s)
DOE	U.S. Department of Energy
EPA	U.S. Environmental Protection Agency
ft	foot (feet)
GAR	Geotechnical Analysis Report
GIS	geomechanical instrumentation system
HWFP	Hazardous Waste Facility Permit
in.	inch(es)
Km	kilometer(s)
kPa	kilopascal(s)
kVA	kilovolt amp(s)
LANL	Los Alamos National Laboratory
lb	pound(s)
m	meter(s)
Ma	million years ago
MB	marker bed
NMED	New Mexico Environment Department
OMB	orange marker bed
psi	pound(s) per square inch
RH	remote-handled
SDD	system design description
SNL/NM	Sandia National Laboratories/New Mexico
SPDV	Site and Preliminary Design Validation

TRU	transuranic
WIPP	Waste Isolation Pilot Plant
WTS	Washington TRU Solutions LLC
yr(s)	year(s)

1.0 Introduction

This Geotechnical Analysis Report (GAR) presents and interprets the geotechnical data from the underground excavations at the Waste Isolation Pilot Plant (WIPP). The data, which are obtained as part of a regular monitoring program, are used to characterize conditions, to compare actual performance to the design assumptions, and to evaluate and forecast the performance of the underground excavations.

GARs have been available to the public since 1983. During the Site and Preliminary Design Validation (SPDV) Program, the architect/engineer for the project produced these reports on a quarterly basis to document the geomechanical performance during and immediately after excavation of the underground facility. Since the completion of the construction phase of the project in 1987, the management and operating contractor for the facility has prepared these reports annually. This report describes the performance and condition of selected areas from July 1, 2003, to June 30, 2004. It is divided into nine chapters. Chapter 1 provides background information on WIPP, its mission, and the purpose and scope of the Geomechanical Monitoring Program. Chapter 2 describes the local and regional geology of the WIPP site. Chapters 3 and 4 describe the geomechanical instrumentation located in the shafts and shaft stations, present the data collected by that instrumentation, and provide interpretation of these data. Chapters 5 and 6 present the results of geomechanical monitoring in the two main portions of the WIPP underground facility (the access drifts and the Waste Disposal Area). Chapter 7 discusses the results of the Geoscience Program, which include fracture mapping and borehole observations. Chapter 8 summarizes the results of the geomechanical monitoring and compares the current excavation performance to the design requirements. Chapter 9 lists the references and bibliography.

1.1 Location and Description

WIPP is located in southeastern New Mexico, 26 miles (42 kilometers [km]) east of Carlsbad (Figure 1-1). The surface facilities were built on the flat to gently rolling hills that are characteristic of the Los Medaños area. The underground facility is being excavated approximately 2,150 feet [ft] (655 meters [m]) beneath the surface in the Salado Formation. Figure 1-2 shows a plan view of the underground configuration of WIPP as of June 30, 2004.

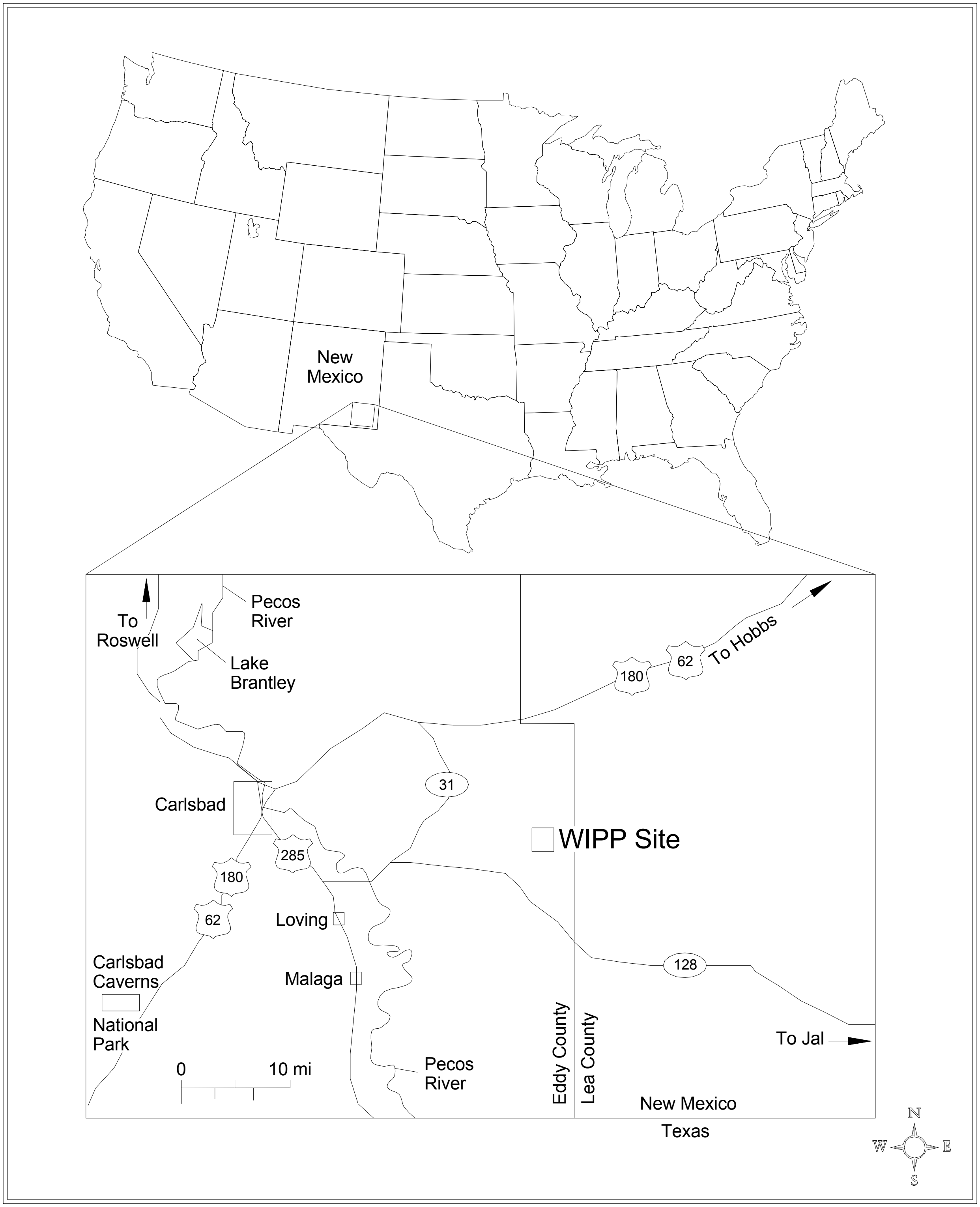

Figure 1-1 WIPP Location

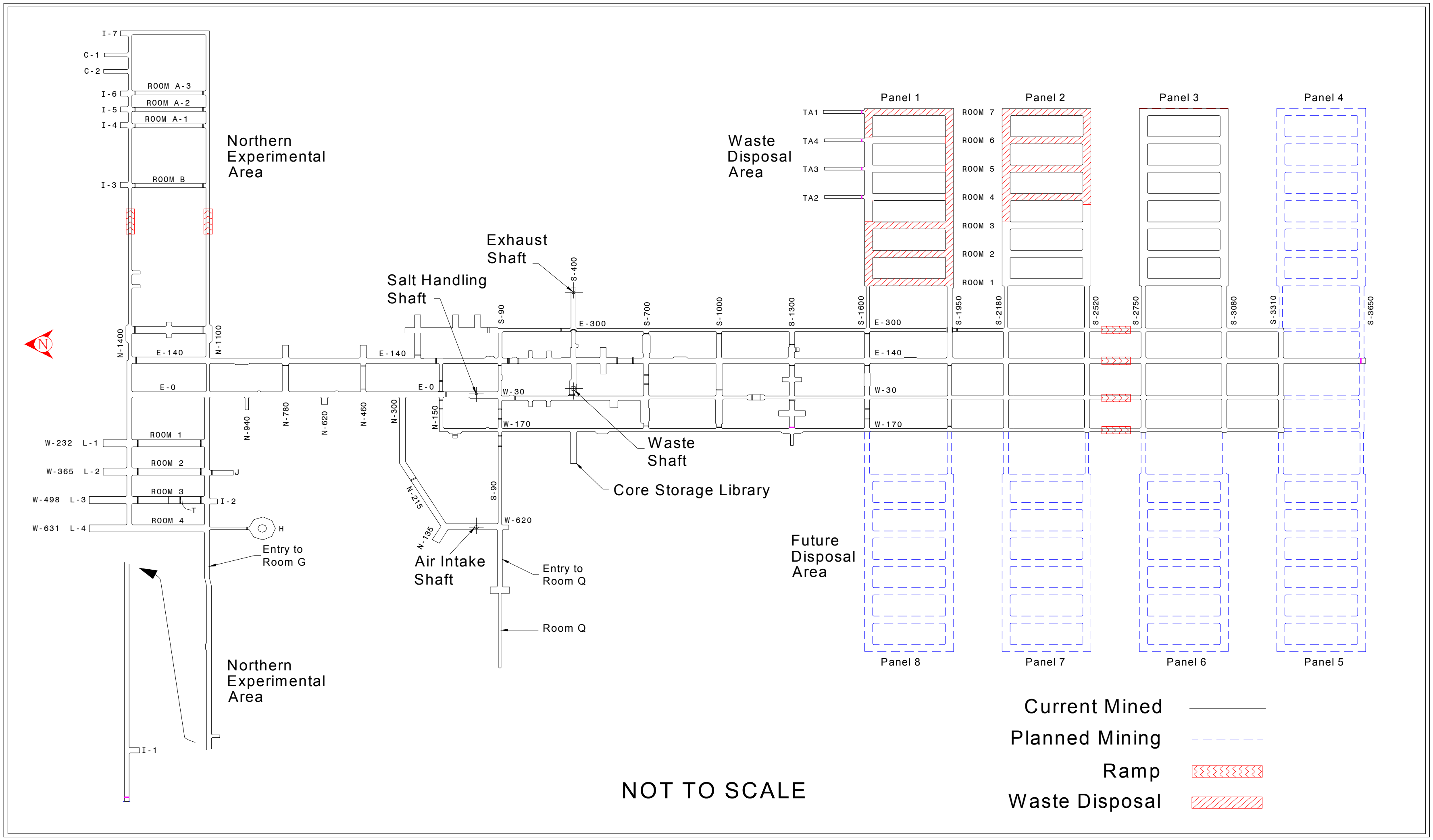

Figure 1-2 Underground Mining and Waste Disposal Configuration as of 6/30/04

1.2 Mission

In 1979 Congress authorized WIPP (Public Law 96-164, National Security and Military Applications of Nuclear Energy Authorization Act of 1980) to provide ". . . a research and development facility to demonstrate the safe disposal of radioactive wastes resulting from the defense activities and programs of the United States exempted from regulation by the Nuclear Regulatory Commission." WIPP is intended to receive, handle, and permanently dispose of transuranic (TRU) waste and TRU mixed waste. To fulfill this mission, the U.S. Department of Energy (DOE) constructed a full-scale facility to demonstrate both technical and operational principles of the permanent disposal of TRU and TRU mixed wastes. Technical aspects are those concerned with the design, construction, and performance of the subsurface excavations. Operational aspects refer to the receiving, handling, and emplacement of TRU wastes in the facility. The facility was also used for *in situ* studies and experiments without the use of radioactive waste.

1.3 Development Status

To fulfill its mission, the DOE developed WIPP in a phased manner. The goal of the SPDV phase, begun in 1980, was to characterize the site and obtain *in situ* geotechnical data from underground excavations to determine whether site characteristics and the *in situ* conditions were suitable for a permanent disposal facility. During this phase, the Salt Handling Shaft, a ventilation shaft, a drift to the southernmost extent of the proposed waste disposal area, a four-room experimental panel, and access drifts were excavated. Surface-based geological and hydrological investigations were also conducted. The data obtained from the SPDV investigations were reported in the "Summary of the Results of the Evaluation of the WIPP Site and Preliminary Design Validation Program" (DOE, 1983).

Based upon the favorable results of the SPDV investigations, additional activities were initiated in 1983. These included the construction of surface structures, conversion of the ventilation shaft for use as the waste shaft, excavation of the Exhaust Shaft, development of additional access drifts to the waste disposal area, excavation of the Air Intake Shaft, and excavation of additional experimental rooms to support research and development activities. Geotechnical data acquired during this phase were used to evaluate the performance of the excavations in the context of established design criteria (DOE, 1984). Results of these evaluations were reported in Geotechnical Field Data Reports (DOE, 1985; DOE, 1986a) and were summarized in the Design Validation Final Report (DOE, 1986b).

The Design Validation Final Report concluded that the facility, including waste disposal areas, could be developed and operated to fulfill the long-term mission of WIPP (DOE, 1986b). However, some modifications to the reference design were proposed so that the requirements could be met for the anticipated life of the waste disposal rooms and the demonstration phase while the waste remained retrievable. The information from these studies validated the design of underground openings to safely accommodate the permanent disposal of waste under routine operating conditions.

Panel 1 mining began in 1986 and was completed in 1988. Panel 1 was intended to receive waste for an initial operations demonstration and pilot plant phase that was scheduled to start in October 1988. However, the demonstration and pilot plant phase didn't happen because waste disposal operation had to wait until permits were acquired.

In October 1996, the DOE submitted to the U.S. Environmental Protection Agency (EPA) a compliance certification application in accordance with Title 40 CFR Parts 191 and 194, which addressed the long-term (10,000-year) performance criterion for the disposal system. On May 18, 1998, the EPA published final certification that allowed for the receipt of TRU waste at WIPP. Immediately prior to this certification, the DOE Carlsbad Area Office (CAO) completed the WIPP Operational Readiness Review, which was required before the start-up of a nuclear waste repository. As a result of the review, the CAO notified the Energy Secretary on April 1, 1998, that WIPP was operationally ready to receive waste. On October 27, 1999, WIPP received the Hazardous Waste Facility Permit (HWFP). On March 26, 1999, the first shipment of TRU waste was received from Los Alamos National Laboratory (LANL). By the end of June 2004, shipments of TRU waste were received at the WIPP site from LANL, Savannah River Site, Hanford Site, Rocky Flats Environmental Technology Site, Idaho National Engineering and Environmental Laboratory, Argonne National Lab-East and the Nevada Test Site.

Waste disposal operations in Panel 1 are complete and panel closures have been constructed in the Panel entries. Mining of Panel 2 began in September 1999 and was completed in August 2000. Mining of Panel 3 began on January 2003 and was completed by the end of March 2004. Mining of the south mains (entry drifts) for Panel 4 was initiated during this reporting period.

1.4 Purpose and Scope of Geomechanical Monitoring Program

As specified in the WIPP HWFP (NMED, 1999), the purpose of the geomechanical monitoring program is to obtain *in situ* data to support the continuous assessment of the design for underground facilities.

Specifically, the program provides for:

- Early detection of conditions that could affect operational safety.
- Evaluation of disposal room closure that ensures adequate access.
- Guidance for design modifications and remedial actions.
- Data for interpreting the behavior of underground openings, in comparison with established design criteria.

Polling of the geomechanical instrumentation is performed at least monthly. Data taken by the geomechanical instrumentation system (GIS) are evaluated and reported in this GAR. This annual report fulfills the requirements set forth in Section IV.F.1 and Attachment M2, Section M2-5b(2) of the WIPP Hazardous Waste Facility Permit (NMED, 1999), and 40 CFR §191.14, "Assurance Requirements," implemented through the certification criteria, 40 CFR Part 194.

The Geomechanical Monitoring Program generates the data for four of the compliance monitoring parameters:

- Creep closure and stresses
- Extent of deformation
- Initiation of brittle deformation
- Displacement of deformation features.

Convergence measurements and borehole extensometers provide data on salt creep closure induced by rock excavation. Data on the extent of deformation are generated through borehole extensometers and borehole observations. Fracture mapping of the excavation surface and borehole observations is used to provide data on the initiation of brittle deformation. Displacement of deformation features in the underground facility is monitored by comparing the results of geologic mapping in newly mined areas to the expected stratigraphy.

The GIS provides data that are collected, processed, and stored for analysis. The following subsections briefly describe the major components of the GIS.

1.4.1 Instrumentation

Instrumentation installed for measuring the geomechanical response of the shafts, drifts, and other underground openings include convergence points, convergence meters, extensometers, rock bolt load cells, pressure cells, strain gauges, piezometers, and joint meters. Table 1-1 lists a summary of the geomechanical instrumentation specifications.

1.4.2 Data Acquisition

The individual geomechanical instruments are read either manually using portable devices or remotely by electronically polling the stations from the surface in accordance with approved operating procedures. Remotely read instruments are connected to one of the data loggers located underground and readings are collected by initiating the appropriate polling routine. Upon completion of a verification process, the data are transferred to a computer database. The manual readout devices are taken to the instrument locations underground. The data are recorded on a data sheet and later entered into an electronic database along with the remotely acquired data.

The underground data acquisition system consists of instruments, polling devices, and a communications network. One or more instruments are connected to a polling device. The polling devices are installed in electrical enclosures near the location of the instrument to facilitate queries of each individual instrument. Polling devices are connected by a datalink to a surface computer.

Whether acquired manually or remotely, geomechanical data are entered into the database files of the GIS data processing system. The data processing system consists of computer programs that are used to enter, reduce, and transfer the data to permanent storage files. Additional routines allow access to these permanent storage files for numerical analysis, tabular reporting, and graphical plotting. Copies of the instrumentation database and data plots are available upon request[3].

[3] Instrumentation data and data plots are presented in "Geotechnical Analysis Report for July 2003-June 2004 Supporting Data." The document is available upon request from the National Technical Information Service. See the back side of this document's cover sheet for details and addresses.

Table 1-1 Geomechanical Instrumentation System

Instrument Type	Measures	Range[a]	Resolution[a]
Sonic probe borehole extensometer	Cumulative deformation	0–2 in.	0.001 in.
Convergence points (Tape Extensometer)	Cumulative deformation	2–50 ft	0.001 in.
Wire convergence meters	Cumulative deformation	0–3.5 ft	0.001 in.
Embedded strain gauges	Cumulative strain	0–3000 μin./in.	1 μin./in.
Spot-welded strain gauges	Cumulative strain	0–2500 μin./in.	1 μin./in.
Rock bolt load cells	Load	0–50 tons	40 lb
Earth pressure cells	Pressure	0–1000 psi	1 psi
Piezometers	Fluid pressure	0–500 psi	0.5 psi
Joint Meters	Cumulative deformation	0–4 in.	0.001 in.
Vibrating wire borehole extensometer	Cumulative deformation	0–4 in.	0.001 in.
Wire borehole extensometer	Cumulative deformation	0–20 in.	0.001 in.
Linear potentiometric borehole extensometer	Cumulative deformation	0–6 in.	0.001 in.

[a] Manual readout boxes for the instruments were manufactured to output measurements in English units. Range and resolution measurement units have not been converted to metric units. Measurements from these instruments <u>have</u> been converted for presentation elsewhere in this report.

ft = foot (feet)
in. = inch(es)
μin. = 10^{-6} inch(es)
psi = pound(s) per square inch
lb = pound(s)

1.4.3 Data Evaluation

Rounding and significant digits are used in the data tables of this document. The reference document that is used is E 29 – 02^{e1}, "Standard Practice for Using Significant Digits in Test Data to Determine Conformance with Specification."[4]

Closure measurements are acquired manually from convergence point anchors and remotely from convergence meters. The data are presented in plots as closure versus time. Closure rate data are calculated and presented as part of the data analysis.

Borehole extensometers provide relative displacement data from instrumented rods anchored at various depths in the rock strata. Displacement is measured relative to a fixed point. The deepest anchor is fixed in what is assumed to be undisturbed ground and is used

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as the reference point. Plots of displacement versus time for individual anchors relative to the reference point are presented. Typically, the plots show greater relative ground movement near the collar (i.e., the opening of the hole). Displacement rate data for the hole collar relative to the deepest anchor are presented in the data analysis.

The annualized closure rate is calculated as follows:

$$
\begin{aligned}
&rate(inches/year) = (cfi_2 - cfi_1)/(date_2 - date_1) \times 365.25\, days/year \\
&where\; cfi = the\; change\; from\; the\; initial\; reading\; (inches) \\
&\qquad cfi_1 = cfi\; reading\; closest\; to\; the\; beginning\; of\; the\; reporting\; period \\
&\qquad cfi_2 = cfi\; reading\; closest\; to\; the\; end\; of\; the\; reporting\; period
\end{aligned}
$$

Rock bolt load cells are used to determine bolt loading. Plots show load versus time for each instrumented bolt.

Earth pressure cells and strain gages are used to determine the stresses and deformation in and around the shaft liners, and data are depicted in time-based plots.

Piezometers used to measure the gage pressure of groundwater are installed in the shafts at varying elevations to monitor the hydraulic head acting on the shaft liners. Data from piezometers are plotted as pressure versus time.

Joint meters, installed perpendicular to a crack, monitor the dilation of the crack with time. Data from these are typically presented as displacement versus time.

1.4.4 Data Errors

As described above, GIS data are processed through a comprehensive database management system. Whether acquired manually or remotely, GIS data are processed and permanently stored according to approved procedures. On occasion, erroneous readings can occur. There are several possible explanations for erroneous readings, including the following:

- The measuring device was misread.
- The reading was recorded incorrectly.

- The measuring device was not functioning within specifications.

When a reading is believed to be erroneous, an immediate evaluation of the previous reading is performed, and a second reading is collected. If the second reading falls in line with the instrument trend, the first reading is discarded and the second reading is entered in the database. If the second reading and subsequent readings remain out of the instrument trend, the ground conditions in the vicinity of the instrument are assessed to determine the reason for the discrepancy. In addition, reading frequency may be increased. This process to correct erroneous readings is documented and filed for future reference.

2.0 Geology

This chapter provides a summary of the stratigraphy of the WIPP region and the facility stratigraphy. Readers desiring further geologic information may consult the "Geological Characterization Report, WIPP Site, Southeastern New Mexico" (Powers et al., 1978). This report was developed as a source document on the geology of the WIPP site for individuals, groups, or agencies seeking basic information on geologic history, hydrology, geochemistry, or detailed information, such as physical and chemical properties of repository rocks. A more recent survey of WIPP stratigraphy is included in Holt and Powers (1990).

2.1 Regional Stratigraphy

The stratigraphy in the vicinity of the WIPP site includes rocks and sediments of Permian (286 to 245 million years ago [Ma]), Triassic (245 to 208 Ma), and Quaternary (1.6 Ma to present) ages. The generalized descriptions of formations provided in this section are given in order of deposition (oldest to youngest), beginning with the Castile Formation (Figure 2-1).

The Permian system in the United States is divided into four series. The last of these, the Ochoan Series, contains the host rock in which the WIPP facility is located. The Ochoan Series is of mostly marine origin and consists of four formations: three evaporite formations (the Castile, the Salado, and the Rustler) and one redbed formation (the Dewey Lake). The Ochoan evaporites overlie marine limestones and sandstones of the Guadalupian Series (Delaware Mountain Group). The younger redbeds represent a transition from the lower evaporite deposition to fluvial deposition on a broad, low-relief, fluvial plain. Fluvial deposits of the Triassic and Quaternary periods complete the stratigraphic column.

2.1.1 Castile Formation

The Castile Formation, lowermost of the four Ochoan formations, is approximately 1,250 ft (380 m) thick in the WIPP vicinity. Lithologically, the Castile is the least complex of the evaporite formations and is composed chiefly of interbedded anhydrite and halite, with limestone present in minor amounts.

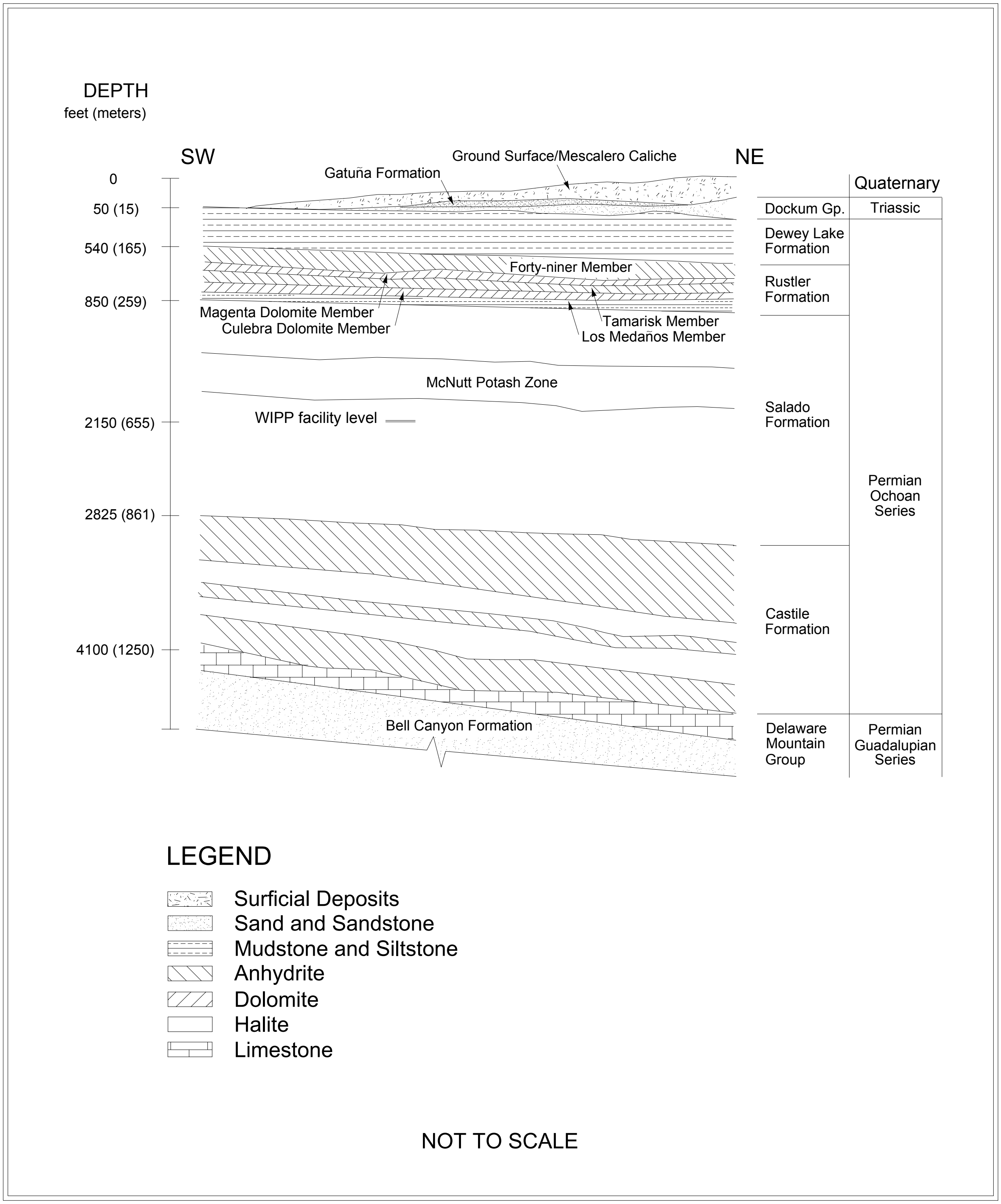

Figure 2-1 Regional Geology

2.1.2 Salado Formation

The Salado Formation comprises nearly 2,000 ft (610 m) evaporites (primarily halite). The formation is subdivided into three informal members: the unnamed lower member, the McNutt potash zone, and the unnamed upper member. Each member contains similar amounts of halite, anhydrite, and polyhalite and is differentiated on the basis of soluble potassium and magnesium-bearing minerals. The WIPP disposal horizon is located within the unnamed lower member, 2,150 ft (655 m) below the surface.

2.1.3 Rustler Formation

The Rustler Formation contains the largest proportion of clastic material of the four Ochoan evaporite formations. The Rustler is subdivided into five members as follows (from the base): the Los Medaños Member, the Culebra Dolomite Member, the Tamarisk Member, the Magenta Dolomite Member, and the Forty-niner Member.

In the vicinity of the WIPP site, the Rustler is approximately 310 ft (95 m) thick and thickens to the east. The lower portion (Los Medaños Member) contains primarily fine sandstone to mudstone with lesser amounts of anhydrite, polyhalite, and halite. Bedded and burrowed siliciclastic sedimentary rocks with cross-bedding and fossil remains signify the transition from the strongly evaporitic environments of the Salado to the brackish lagoonal environments of the Rustler (Holt and Powers, 1990).

The upper portion of the Rustler contains interbeds of anhydrite, dolomite, and mudstone. The Culebra Dolomite member is generally brown, finely crystalline and locally argillaceous. The Culebra contains rare to abundant vugs with variable gypsum and anhydrite filling and is the most transmissive hydrologic unit within the Rustler. The Tamarisk Member consists of lower and upper sulfate units separated by a unit that varies laterally from mudstone to mainly halite. The Magenta Dolomite Member is a gypsiferous dolomite with abundant primary sedimentary structures and well-developed algal features. The Forty-niner Member consists of lower and upper sulfate units separated by a mudstone that displays sedimentary features and bedding. East of the site area, halite correlates with the mudstone. The Culebra and Magenta Dolomite members are persistent and serve as important marker units.

2.1.4 Dewey Lake Redbeds

The Dewey Lake Redbeds are the uppermost of the Ochoan Series formations in the WIPP vicinity. Within the series, the Dewey Lake represents a transition from the lower marine-influenced evaporite deposition to fluvial deposition on a broad, low-relief, fluvial plain. The redbeds, approximately 475 ft (145 m) thick, consist of predominantly reddish-brown interbedded fine-grained sandstone, siltstone, and claystone. The formation is differentiated from other formations by its lithology and distinctive color (both of which are remarkably uniform), and sedimentary structures, including horizontal- and cross-laminae and ripple marks. The redbeds also contain locally abundant greenish-gray reduction spots and gypsum-filled fractures. The formation thickens from west to east due to eastward dips and erosion to the west.

2.1.5 Dockum Group

The Dockum Group consists of fine-grained floodplain sediments and coarse alluvial debris of the Triassic age. At the WIPP site, the Dockum Group pinches out near the center of the site and thickens eastward as an erosional wedge. Local subdivisions of the Dockum Group are the Santa Rosa Sandstone and the Chinle Formation; however, only the Santa Rosa occurs in the vicinity of the site. The Santa Rosa consists primarily of poorly sorted sandstone with conglomerate lenses and thin mudstone partings and contains impressions and remnants of fossils. These rocks have more variegated hues than the underlying uniformly colored Dewey Lake.

2.1.6 Gatuña Formation, Mescalero Caliche, and Surficial Sediments

Quaternary Period deposits include the Gatuña Formation, Mescalero Caliche, and surficial sediments. The Gatuña Formation (ranging in age from approximately 13 Ma to 600,000 years before present [b.p.] [Powers and Holt, 1993]) is a stream-laid deposit overlying the Dockum Group in the WIPP vicinity. At the site center the formation consists of approximately 13 ft (4 m) of poorly consolidated sand, gravel, and silty clay. The Gatuña Formation is light red and mottled with dark stains. The unit contains abundant calcium carbonate, but is poorly cemented. Sedimentary structures are abundant (Powers and Holt, 1993, 1995).

The Mescalero Caliche (approximately 500,000 years b.p.) is approximately 4 ft (1.2 m) thick in the WIPP vicinity. The Mescalero is a hard, resistant soil horizon that lies beneath a cover of wind-blown sand. The horizon is petrocalcic, or very strongly cemented with calcium carbonate. Petrocalcic horizons form slowly beneath a stable landscape at the average depth of infiltration of soil moisture and are an indicator of stability and integrity of the land surface. Many of the surface buildings at WIPP are founded on top of the Mescalero Caliche.

Surficial sediments include sandy soils developed from eolian material and active dune areas. The Berino Series (a soil type) covers about 50 percent of the site and consists of deep sandy soils that developed from wind-worked material of mixed origin. Based on sample analyses, the Berino soil from the WIPP site formed 330,000 ± 75,000 years ago.

2.2 Underground Facility Stratigraphy

The WIPP disposal horizon lies in the approximate center of the Salado Formation. The Salado was deposited in a shallow saline lagoon environment, which progressed through numerous inundation and desiccation cycles that are reflected in the formation. An "ideal" cycle progresses upward as follows: a basal layer consisting predominantly of claystone, followed by a layer of sulfate, which is in turn followed by a layer of halite. The entire sequence is capped by a bed of argillaceous (clay-rich) halite accumulated during a period of mainly subaerial exposure.

A regional system used for numbering the more significant sulfate beds within the Salado designates these beds as marker beds (MB) 100 (near the top of the formation) to MB144 (near the base). The repository is located between MB138 and MB139 (Figure 2-2) within a sequence of laterally continuous depositional cycles as described above. Within this sequence, layers of clay and anhydrite that are locally designated (as shown) can have a significant impact on the geomechanical performance of the excavations. Clay layers provide surfaces along which slip and separation can occur, whereas anhydrite acts as a brittle unit that does not deform plastically.

In the vicinity of the WIPP facility, the stratigraphy is fairly continuous and uniform. The stratigraphic beds generally dip towards the south-southeast at a slope of approximately 3 percent.

2.2.1 Disposal Horizon Stratigraphy (Panels 1, 2, 7, and 8)

This disposal horizon contains panels 1, 2, 7, and 8, all the shaft areas, the shop areas, the SPDV areas (which are now closed to access), and all the access drifts to South 2620. The four main entries that extend south ramp-up starting at South 2620 and complete at South 2740.

Most underground excavations are located within this disposal horizon (see Figure 2-2). In this horizon, the Orange Marker Bed (OMB) typically occurs near mid-rib. The OMB is a laterally consistent unit of moderate to light reddish-orange halite, typically about 6 in. (15 centimeters [cm]) thick, that is used as a point of reference for disposal area excavation.

MB139 typically lies approximately 5 ft (1.5 m) below the excavation floor. MB139 is a 20-to-32 in. (50-to-80 cm) thick layer of polyhalitic anhydrite. The top of the anhydrite undulates up to 15 in. (38 cm) while the bottom is sub-horizontal and is underlain by clay "E." Above MB139 is a unit of halite that terminates at the base of the OMB. Within this unit, polyhalite is locally abundant and decreases upward, while argillaceous material increases upward.

Above the OMB, a thin sequence of argillaceous halite gives way to a thick sequence of clear halite that becomes increasingly argillaceous upward and is capped by clay "F." Clay "F" occurs as a thin layer occasionally interrupted by partings and breaks and is readily visible in the upper ribs of disposal horizon excavations.

Above clay "F," another sequence of halite begins that, as in lower sequences, becomes increasingly argillaceous upward. This sequence terminates at the clay "G"/Anhydrite "b" interface, approximately 6.5 ft (2 m) above the roof of most disposal horizon excavations, forming a roof beam that typically acts as a unit. The roof of some disposal horizon excavations (e.g., East 140 drift between South 1000 and South 1950) has been excavated to the upper contact of Anhydrite "b." In this case, a roof beam is formed by the next depositional sequence beginning with Anhydrite "b" and progressing upward to the clay "H"/Anhydrite "a" interface, typically approximately 6.5 ft (2 m) above the upper contact of Anhydrite "b."

2.2.2 Disposal Horizon Stratigraphy (Panels 3, 4, 5, and 6)

This disposal horizon contains Panels 3, 4, 5, 6, and all the access drifts south of South 2740. The rise in floor elevation from South 2620 to South 2740 is approximately 6 ft.

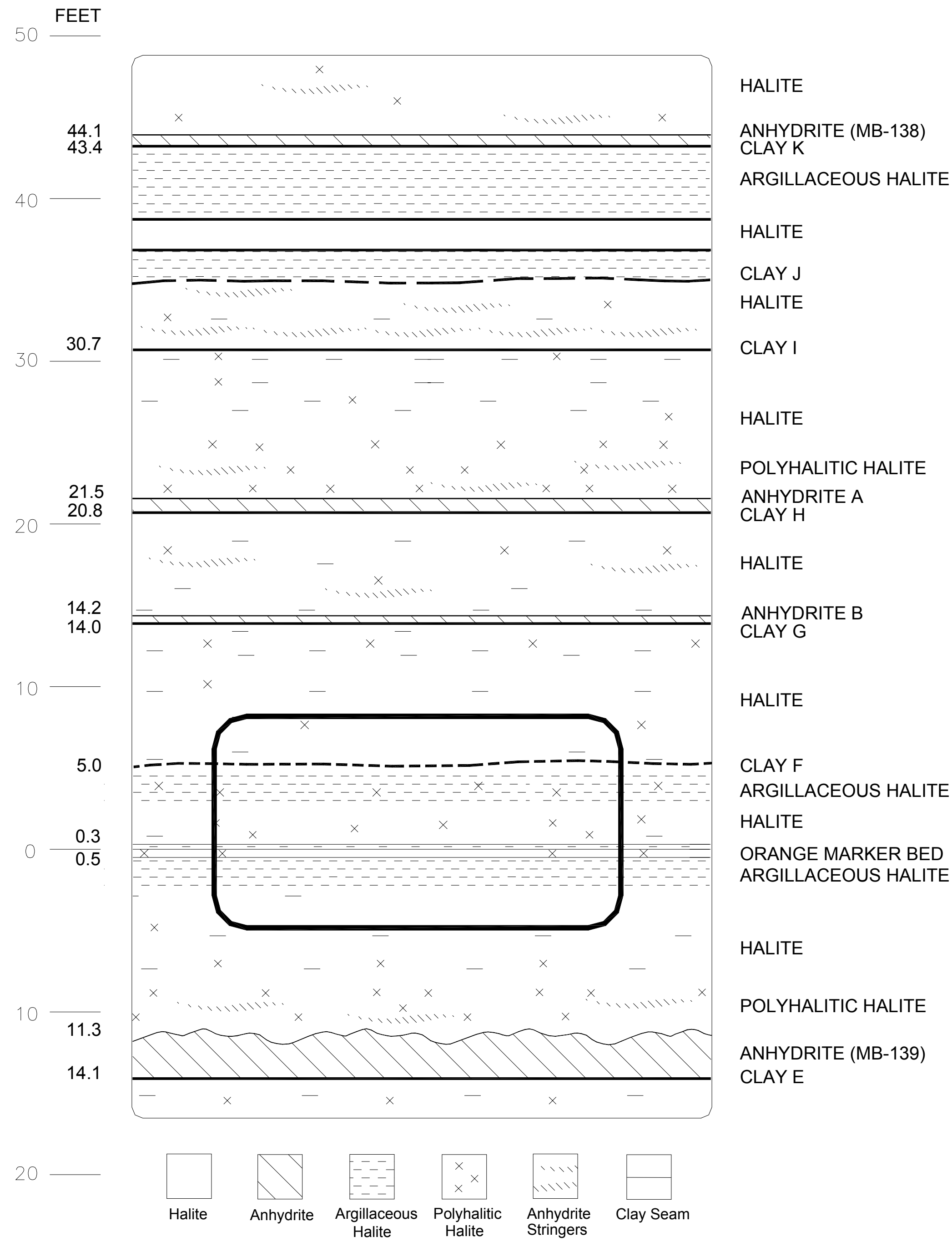

Figure 2-2 Repository Level Stratigraphy (Panels 1, 2, 7 and 8)

In this horizon (see Figure 2-3), the OMB typically occurs at or below the floor. MB139 typically lies about 12 ft (3.7 m) below the excavation floor. This sequence terminates at the clay "G"/Anhydrite "b" interface. The roof is immediately above Anhydrite "b." Clay "G"/Anhydrite "b" is used as the mining reference at this disposal horizon.

2.2.3 Northeast Area Stratigraphy

All of the Northeast Area, an experimental area, is now deactivated and closed to access. These excavations lie at a higher stratigraphic level than the disposal excavations. They typically have floors excavated at Anhydrite "b." As in the lower units, the halite intervals between the clay seams/anhydrite beds contain relatively pure halite that becomes increasingly argillaceous upward. Above clay "I," two more halite intervals complete the underground facility stratigraphy. Clay "J," at the top of the first of these intervals, may occur as a distinct seam or merely an argillaceous zone. Clay "K" tops the second interval and is overlain by anhydrite MB138.

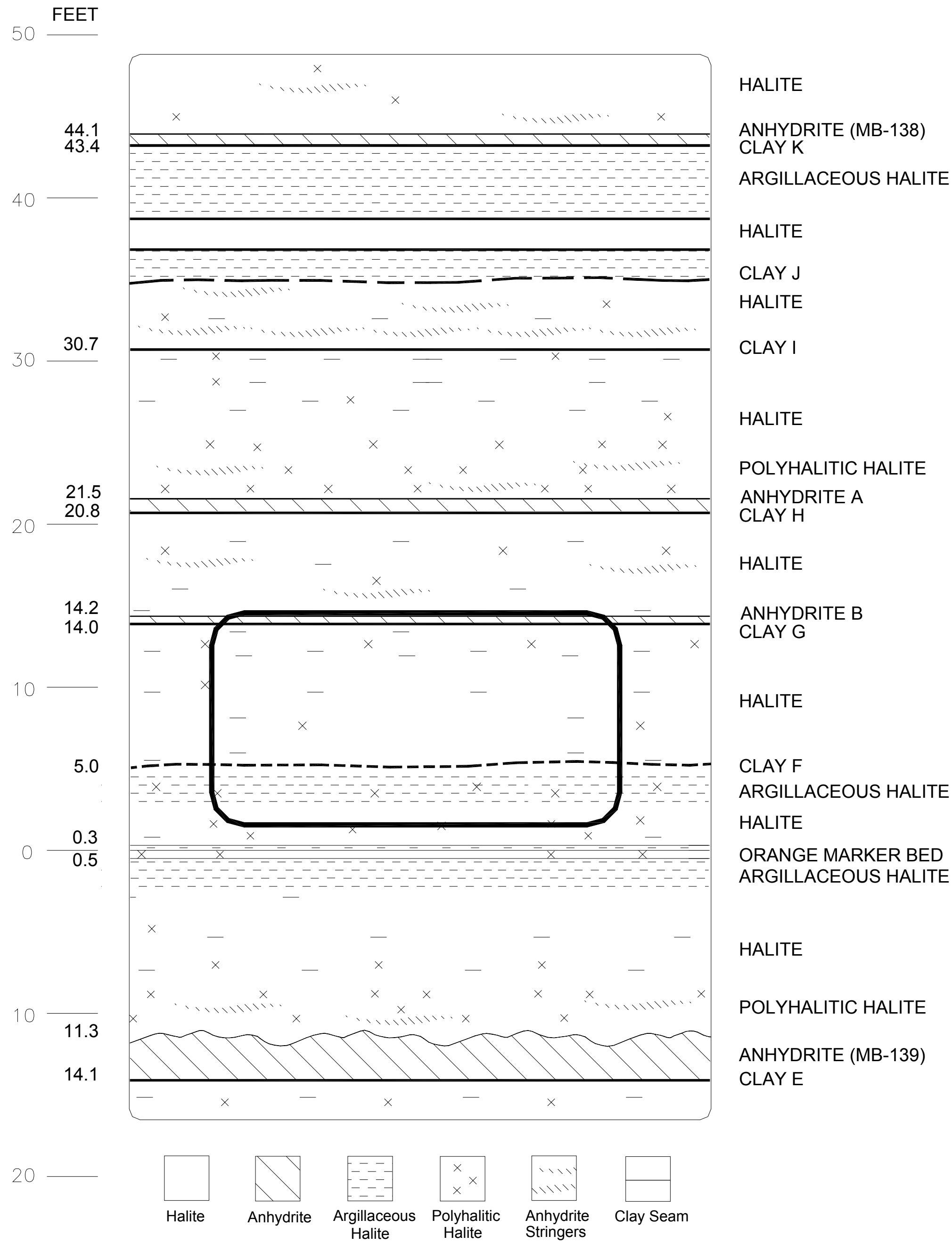

Figure 2-3 Repository Level Stratigraphy (Panels 3, 4, 5 and 6)

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3.0 Performance of Shafts and Keys

Four shafts connect the surface with the WIPP underground facility. The four shafts are: the Salt Handling Shaft, which is primarily used for removing excavated salt from the underground; the Waste Shaft, which is the primary shaft for transporting men and materials and is used for transporting TRU waste to the underground; the Exhaust Shaft, which is used to exhaust the ventilation air from the underground; and the Air Intake Shaft, which is the primary source of fresh air ventilation to the underground. This chapter describes the geomechanical performance of these shafts.

Although through the years some of the shaft instrumentation has failed, there are no plans to replace failed instrumentation installed in any of the shafts. The project currently has a good understanding of the expected movements in the shafts. The monitoring results, up to the point of instrument failure, did not indicate any unusual shaft movements or displacements. Continued periodic visual inspections confirm the expected shaft performance and provide necessary observations to evaluate shaft performance. It is anticipated that replacement of the failed instrumentation will not provide significant additional information.

3.1 Salt Handling Shaft

The first construction activity undertaken during the SPDV Program was the excavation of the Exploratory Shaft. This shaft was subsequently referred to as the Construction and Salt Handling Shaft and is currently designated the Salt Handling Shaft (see Figure 1-2). The shaft was drilled from July 4 to October 24, 1981, and geologic mapping was conducted in the spring of 1982 (DOE, 1983). Figure 3-1 presents the stratigraphy at the Salt Handling Shaft.

The Salt Handling Shaft is lined with steel casing and has a 10-ft (3-m) inside diameter from the ground surface to a depth of 846 ft (257.9 m). The steel liner has a thickness of 0.62 in. (1.6 cm) at the top, increasing with depth to a thickness of 1.5 in. (3.8 cm), including external stiffener rings, at the key. Cement grout is placed between the liner and rock face. The 10-ft (3-m) diameter extends through the concrete shaft key to a depth of 880 ft (268.2 m). The shaft key is a 37.5-ft (11.4-m) long, reinforced-concrete structure that begins 3.5 ft (1.07 m) above the bottom of the steel liner. The shaft from the key to the bottom of the shaft, at a depth of 2,298 ft (700 m), has a nominal diameter of 12 ft (4 m).

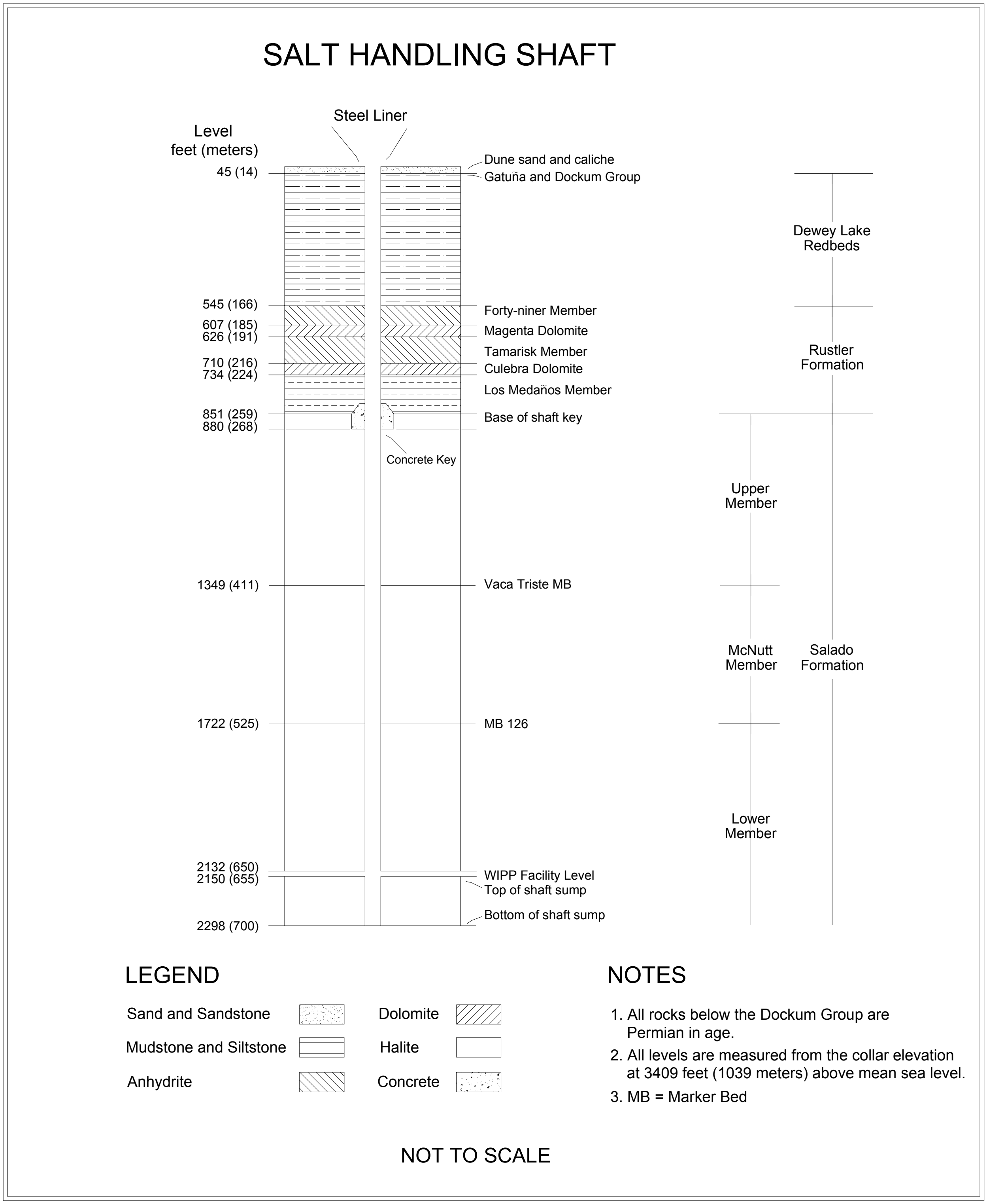

Figure 3-1 Salt Handling Shaft Stratigraphy

Wire mesh anchored by rock bolts is installed in this portion as a safety screen to contain rock fragments that may become detached. The shaft extends approximately 140 ft (43 m) below the facility horizon in order to accommodate the skip loading equipment and to act as a sump.

3.1.1 Shaft Observations

Underground operations personnel conduct weekly visual shaft inspections. These inspections are performed principally to assess the condition of the hoisting and mechanical systems, but they also include examining the shaft walls for water seepage, loose rock, or sloughing. The visual shaft inspections during this reporting period found that the Salt Handling Shaft was in satisfactory condition. Only routine ground control activities were required in the Salt Handling Shaft during this reporting period.

3.1.2 Instrumentation

Geomechanical instruments (radial convergence points, extensometers, and piezometers) were installed at various levels in the Salt Handling Shaft from April through July of 1982 (Figure 3-2). In the shaft key, instruments included strain gages, pressure cells, and piezometers (Figure 3-3). The radial convergence points were installed prior to the outfitting of the Salt Handling Shaft. Upon completion of the outfitting, no more readings were taken. All of the extensometers in the Salt Handling Shaft are nonfunctional.

All 12 piezometers continue to provide data. The fluid pressures recorded at the end of this reporting period range from approximately 86 pounds per square inch (psi) (593 kilopascals [kPa]) at the 580-ft (177-m) level in the Forty-niner Member to 171 psi (1,130 kPa) at the 691-ft (211-m) level in the Tamarisk Member. The recorded pressure of 163 psi (1123 kPa) at the Magenta Dolomite Member represents a 73-psi increase; however, the installations at this level have historically exhibited large fluctuations. The recorded pressures of 143 psi (986 kPa) at the Culebra Dolomite Member represent no significant change from the recorded pressure in the same location at the end of the previous reporting period. The fluid pressure on the shaft liner will continue to be monitored on a regular basis.

Four earth pressure cells were installed in the key section of the Salt Handling Shaft during concrete emplacement at the 860-ft (262-m) level. These instruments measure the normal stress between the concrete key and the Salado Formation as the creep effects load on the key structure. Three of the four earth pressure cells continue to provide data. These

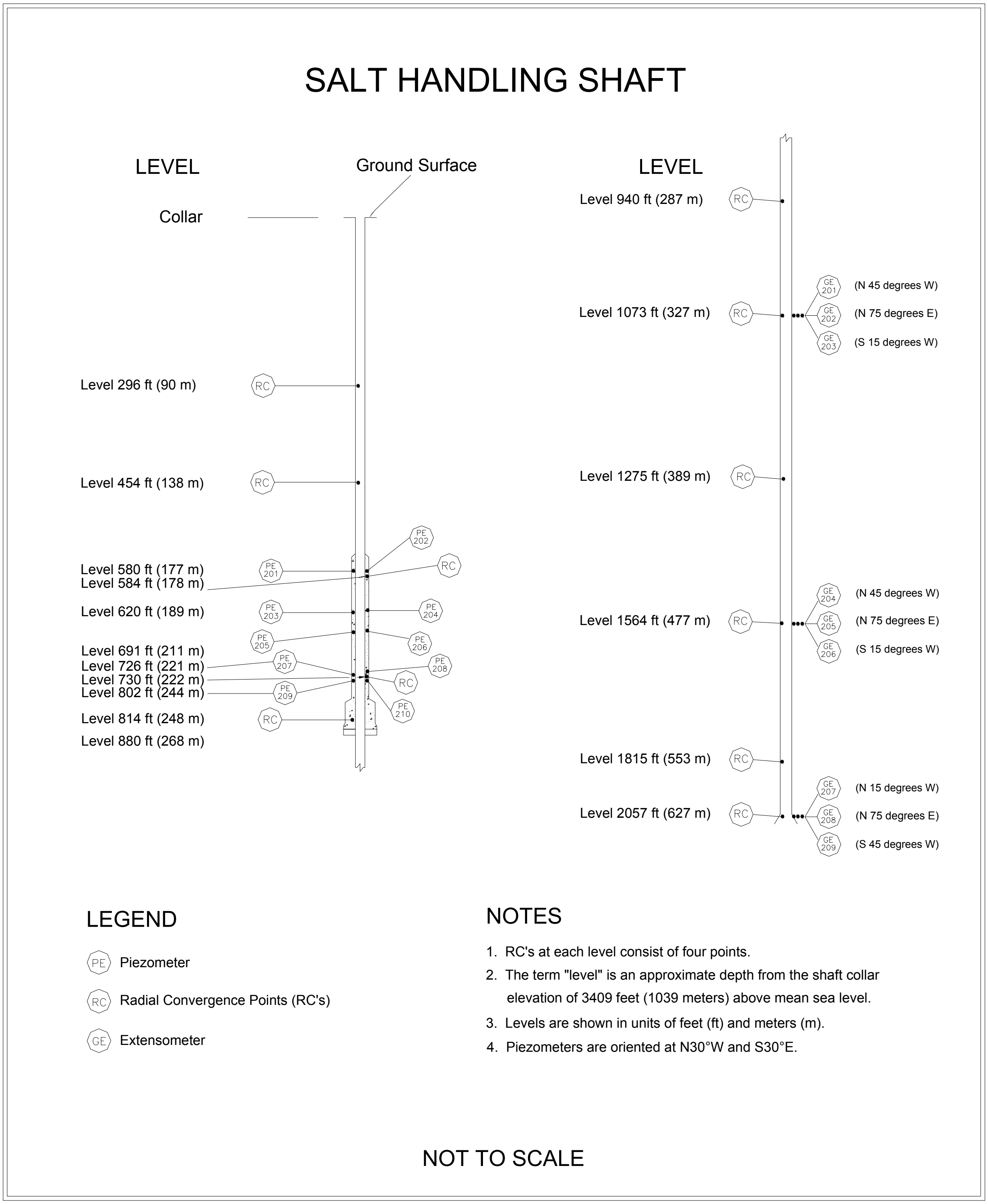

Figure 3-2 Salt Handling Shaft Instrumentation (Without Shaft Key)

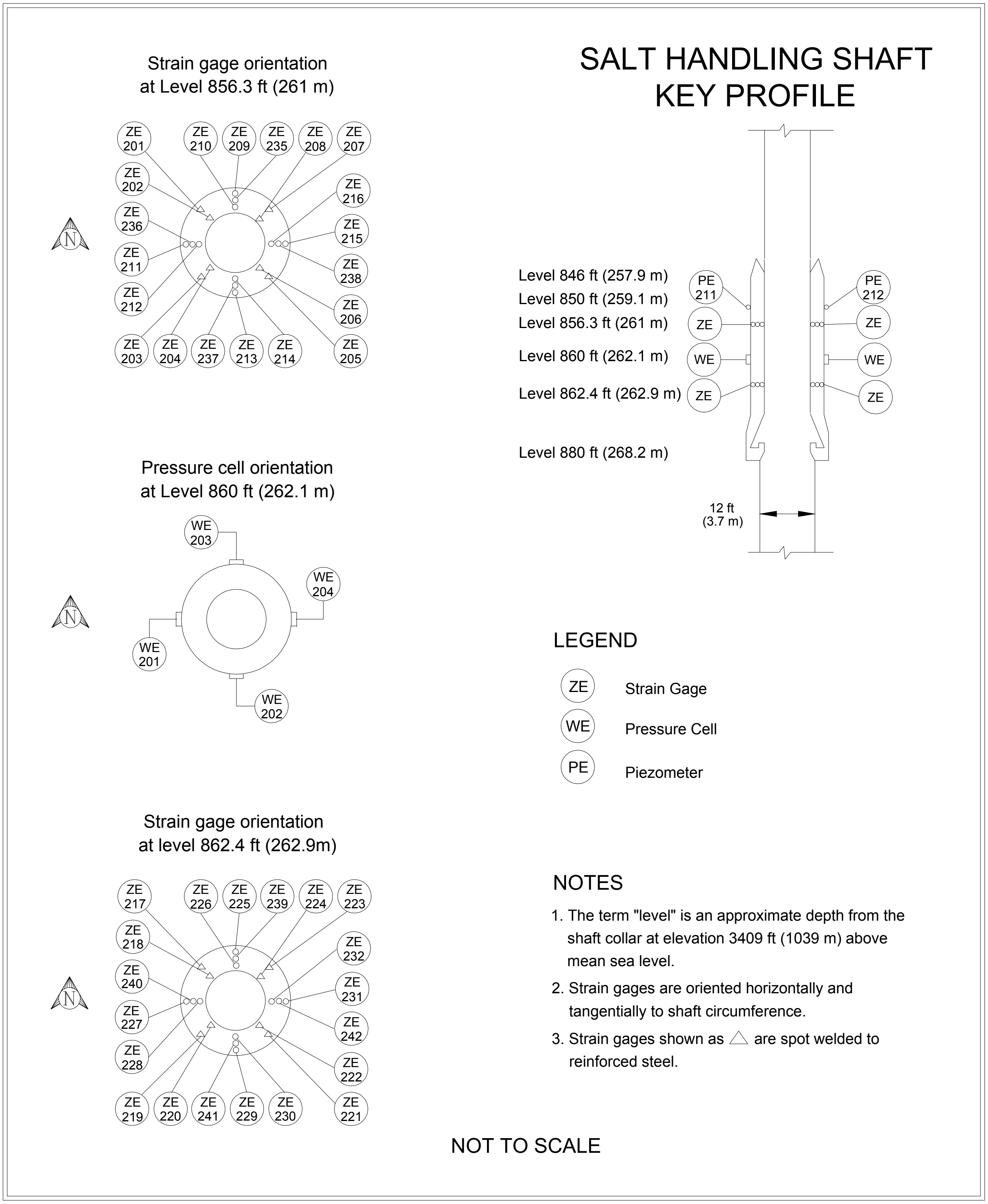

Figure 3-3 Salt Handing Shaft Key Instrumentation

instruments have essentially indicated no contact pressure since their installation (readings resemble instrument drift at a zero pressure). The contact pressures recorded by the instruments for this reporting period ranged from -20 to 2 psi (-146 to 14 kPa).

Sixteen spot-welded and 24 embedment strain gages were installed on and in the shaft key concrete at both the 856.3-ft (261-m) level and at the 862.4-ft (262.9-m) level. There are four functioning spot-welded strain gages located at these levels. The reported strains at the 856.3-ft (261-m) level were 670 and 759 microstrain. The reported strains at the 862.4-ft (262.9-m) level were 565 and 837 microstrain. The strains reported for this reporting period from the 12 embedment strain gages located at the 856.3-ft (261-m) level range from -802 microstrain to 991 microstrain. The strains reported for this reporting period from the two embedment strain gages located at the 862.4-ft (262.9-m) level were 183 microstrain to 320 microstrain. The strains recorded from the spot-welded strain gages and the embedment strain gages are very similar to the recorded strains from these instruments at the end of the previous reporting period.

3.2 Waste Shaft

As part of the SPDV Program, a 6-ft (2-m) diameter ventilation shaft, now referred to as the Waste Shaft, was excavated from December 1981 through February 1982 (see Figure 1-2). This shaft, in combination with the Salt Handling Shaft, provided a two-shaft underground air circulation system. From October 11, 1983, to June 11, 1984, the shaft was enlarged to a diameter of 20 to 23 ft (6 to 7 m) and lined above the key. Stratigraphic mapping (Figure 3-4) was conducted during shaft enlargement from December 9, 1983, to June 5, 1984 (Holt and Powers, 1984).

The Waste Shaft is lined with nonreinforced concrete and has a 19 ft (6 m) inside diameter from the ground surface to the top of the Waste Shaft key at 837 ft (255 m). Liner thickness increases with depth from 10 in. (25 cm) at the surface to 20 in. (51 cm) at the key. The Waste Shaft key is 63 ft (19 m) long and 4.25 ft (1.3 m) thick and is constructed of reinforced concrete. The bottom of the key is 900 ft (274 m) below the surface. The diameter of the shaft is 20 ft (6 m) at the point below the key and increases to 23 ft (7 m) just above the shaft station. The shaft below the key is lined with wire mesh anchored by rock bolts. The diameter of 23 ft (7 m) extends to a depth of approximately 2,286 ft (697 m) with the shaft sump comprising the lower 119 ft (36 m) of that interval.

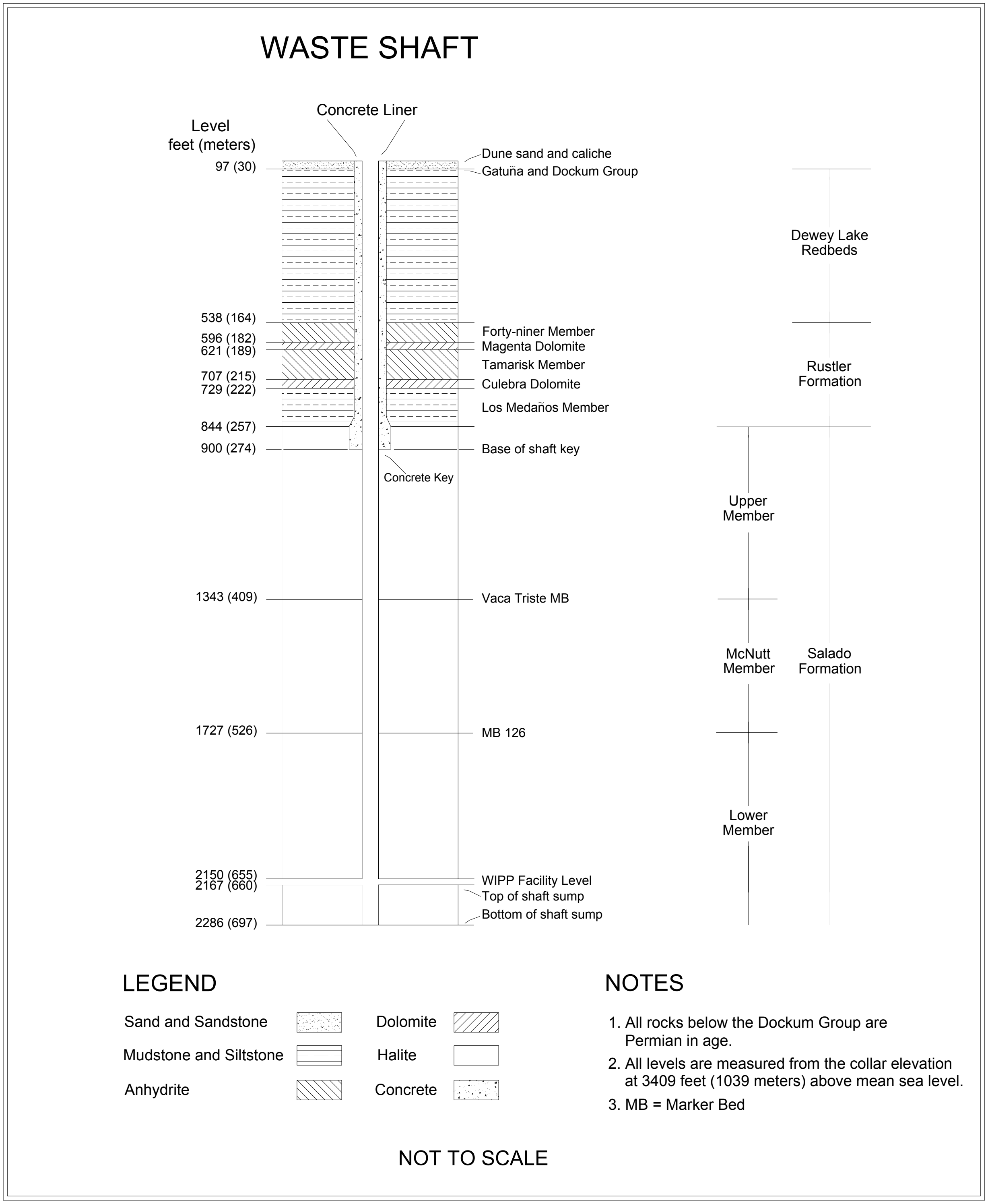

Figure 3-4 Waste Shaft Stratigraphy

3.2.1 Shaft Observations

Underground operations personnel conduct weekly visual shaft inspections. These inspections are performed principally to assess the condition of the hoisting and mechanical systems, but also include observation of the shaft walls for water seepage, loose rock, or sloughing. The visual shaft inspections during this reporting period found that the Waste Shaft was in satisfactory condition. No ground control activities other than routine maintenance were required in the Waste Shaft during this reporting period.

3.2.2 Instrumentation

Radial convergence points, extensometers, piezometers, and earth pressure cells were installed in the Waste Shaft between August 27 and September 10, 1984. Figures 3-5 and 3-6 illustrate the instrumentation configurations in the shaft and shaft key. The radial convergence points were installed prior to the outfitting of the Waste Shaft. Upon completion of the outfitting, no more radial convergence readings were taken.

Nine multiposition borehole extensometers were installed in arrays at 1,071 ft (326 m), 1,566 ft (477 m), and 2,059 ft (628 m) below the surface as shown in Figure 3-5. Each array consists of three extensometers. Currently, six out of nine extensometers remain functional; however, no data has been collected during this reporting period due to the malfunction of the data-logger.

Twelve piezometers were installed in the lined section of the Waste Shaft on September 7 and 8, 1984, to monitor fluid pressure behind the shaft liner and key section in the shaft. Data continue to be received from all 12 piezometers.

Four earth pressure cells were installed in the key section of the Waste Shaft during concrete emplacement between March 23 and April 3, 1984. These instruments measure the normal stress between the concrete key and the Salado Formation as the salt creep loads the key structure.

During this reporting period the Waste Shaft instrumentation data-logger, which records all the data for the borehole extensometers, the piezometers and the earth pressure cells, was nonfunctional. Therefore, comparisons to previous reporting period data is not available.

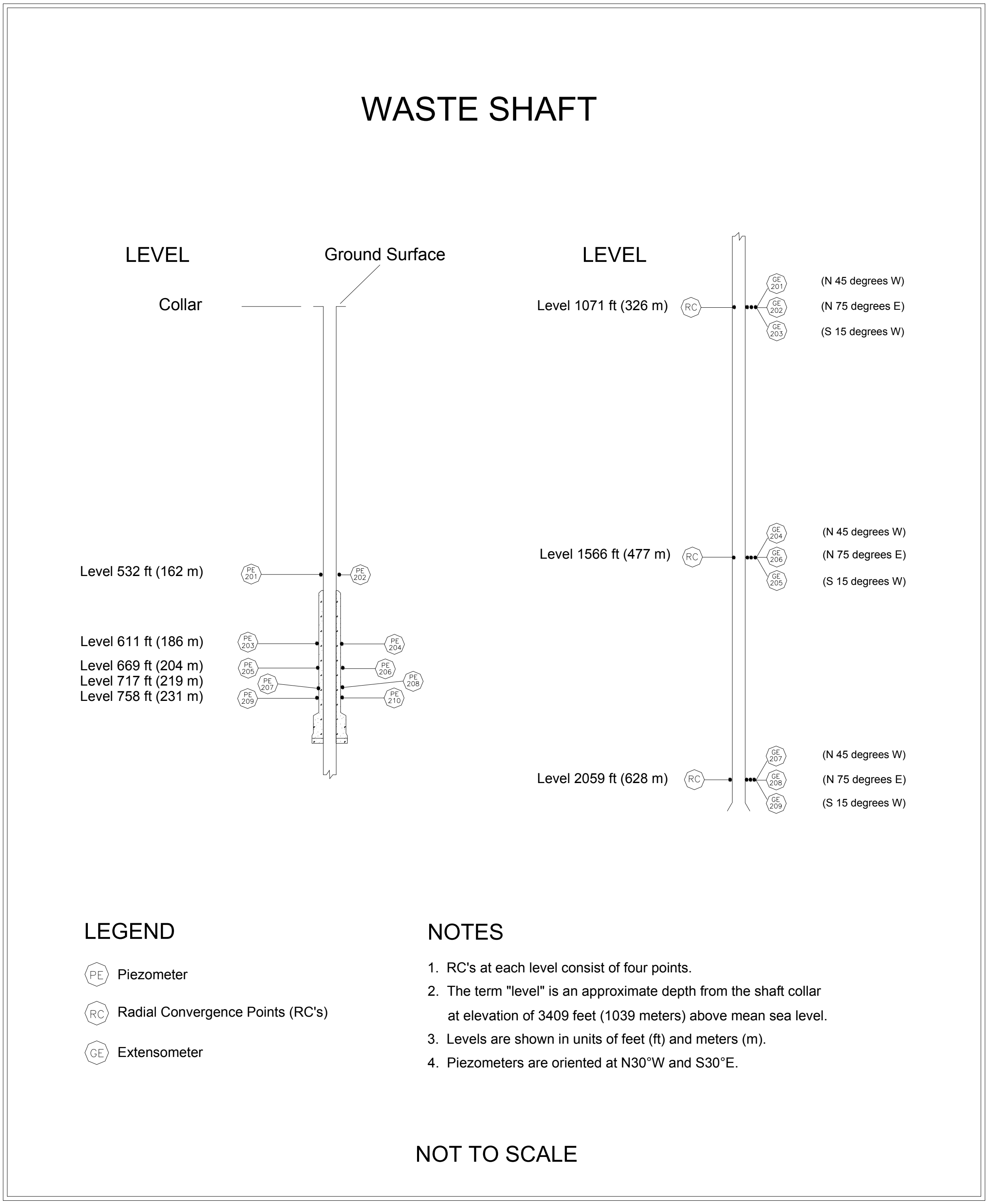

Figure 3-5 Waste Shaft Instrumentation (Without Shaft Key)

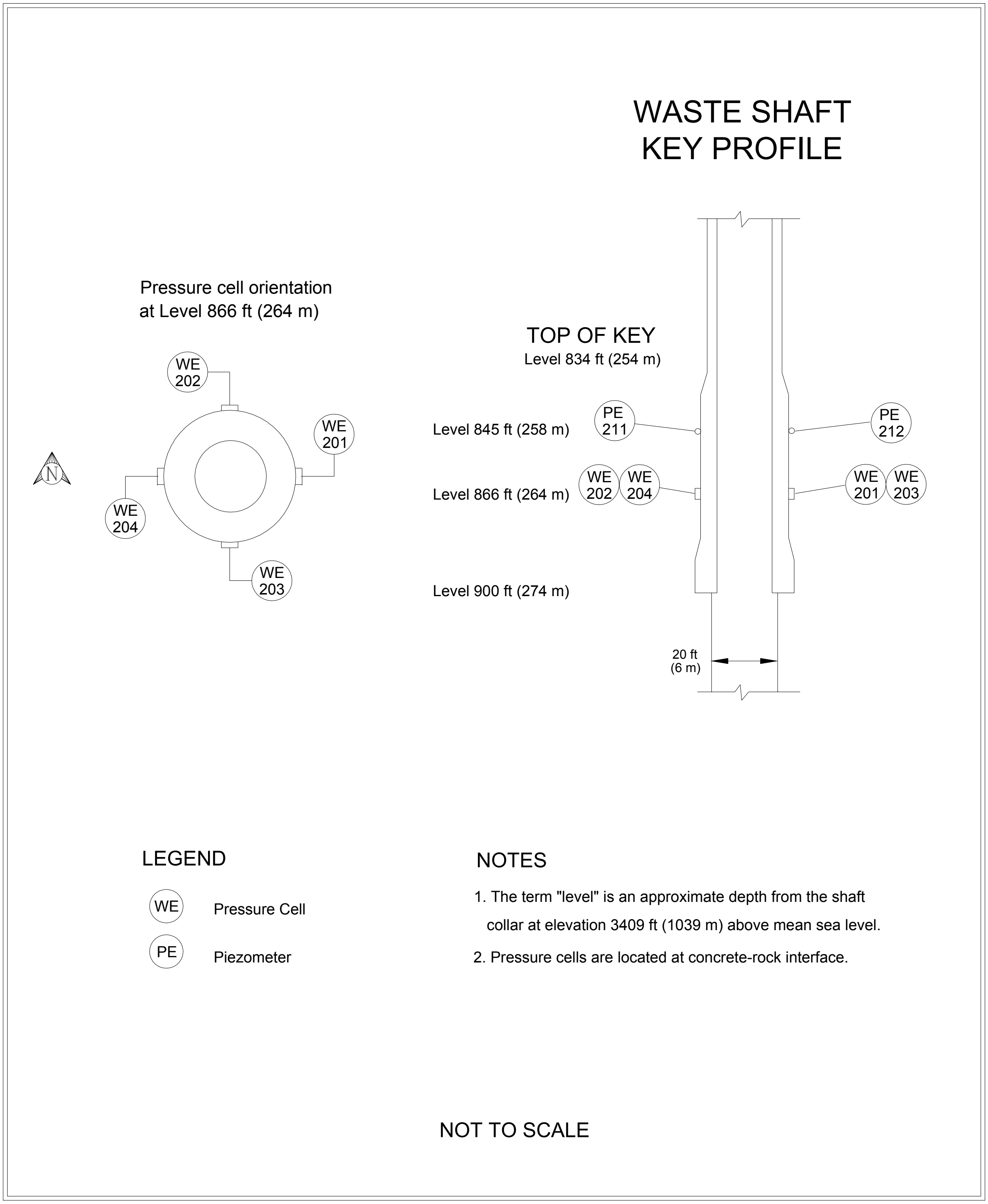

Figure 3-6 Waste Shaft Key Instrumentation

3.3 Exhaust Shaft

The Exhaust Shaft was drilled from September 22, 1983, to November 29, 1984, to establish a route from the underground facility to the surface for exhaust air (see Figure 1-2). Stratigraphic mapping was conducted from July 16, 1984, to January 18, 1985 (DOE, 1986c). Figure 3-7 illustrates the Exhaust Shaft Stratigraphy.

The Exhaust Shaft is lined with nonreinforced concrete from the surface to the top of the shaft key at a depth of 844 ft (257 m). The liner thickness increases from 10 to 16 in. (25 to 41 cm) over that interval. The Exhaust Shaft key is 63 ft (19 m) long and 3.5 ft (1 m) thick. The shaft diameter below the key is 15 ft (5 m) and the interval below the key is lined with wire mesh anchored by rock bolts. The shaft terminates at the facility horizon, at a depth of approximately 2,150 ft (655 m). There is no excavated shaft sump.

3.3.1 Exhaust Shaft Observations

Quarterly Exhaust Shaft video inspections are conducted following approved WIPP procedures. Inspections are performed to evaluate the condition and to verify the integrity of the shaft. The shaft is examined for cracks, corrosion, salt buildup, leaks, and debris. In addition, inspections examine the condition of anchors, brackets, and down-hole equipment. Between July 2003 and June 2004, four shaft inspections were conducted. Inspections were conducted on August 13, 2003; October 29, 2003; February 20, 2004; and May 5, 2004.

3.3.1.1 Video Camera

Video inspections of the Exhaust Shaft were conducted by the Washington TRU Solutions LLC (WTS) Geotechnical Engineering Section using a custom-designed vertical-drop camera. The system consists of a color camera with pan, tilt, and zoom capability. The camera is housed in an aerodynamic housing and suspended by a dual-armored cable. The cable consists of five copper conductors and two multimode optical fibers. The cable is reeled out by a winch mounted in a control van. The video inspections are recorded on VHS tape.

3.3.1.2 Shaft Inspection Observations

Quarterly video inspection observations concentrate on four major areas: air monitoring systems, shaft liner, shaft walls, and equipment support and cabling. The air monitoring components consist of one air-velocity and three air-monitoring devices in the Exhaust

Shaft, as shown in Figure 3-8. The video inspection includes examination of each device, including the transport assembly, guide tubes, the sample intake, and the support brackets that extend from Station A located above the shaft to the Exhaust Shaft collar. From the Exhaust Shaft collar, the air monitoring components extend down 21 ft and into the shaft. Video inspections indicate that the air-sampling components may typically accumulate salt buildup of up to several inches.

The Exhaust Shaft liner is examined for cracks, seepage, and general shaft stability. Currently, there are three principal zones of seepage in the shaft. The first is at a depth of about 50 to 55 ft below the shaft collar (bsc). The second is at a depth of about 60 to 65 ft bsc. The third is at a depth of about 75 to 80 ft bsc, as shown in Figure 3-9. Monitoring of seepage horizons dates back prior to 1995. Water entering the shaft through these cracks is believed to originate from a perched anthropogenic water-bearing horizon at the base of the Santa Rosa Formation. The fluid level in the Santa Rosa near the shaft is at about 42 ft below ground surface. Based on examination of the inspection videos the flow rate into the shaft is estimated at about 1 to 3 gallons per minute.

Conditions in the shaft change as a function of several variables, including airflow, humidity, temperature, and underground mining activities (dust). The seepage cracks noted above are confined primarily to the eastern side of the shaft wall. During this reporting period, there did not appear to be any significant change in the quantity of fluid entering the shaft. This is confirmed by comparing annual records of the volume of fluid accumulating in the Exhaust Shaft catch basin at the bottom of the Exhaust Shaft.

When fluid was detected seeping into the Exhaust Shaft in 1995, a catch basin was designed and installed at the base of the Exhaust Shaft to intercept and prevent water from draining into the Waste Shaft Sump. Fluid has been removed on an as-needed basis from the catch basin since March 1996. Table 3-1 presents the volume of fluid removal from the catch basin from July 1997 through June 2004. Between July 2003 and June 2004, the volumes of fluid removed from the catch basin ranged from 55 gallons to 660 gallons (Table 3-1). The largest reported volumes are typically associated with periods of reduced ventilation and increased humidity. For a discussion of the factors affecting the quantity of fluid entering the Exhaust Shaft catch basin, refer to DOE/WIPP 00-2000, "*Brine Generation Study*."

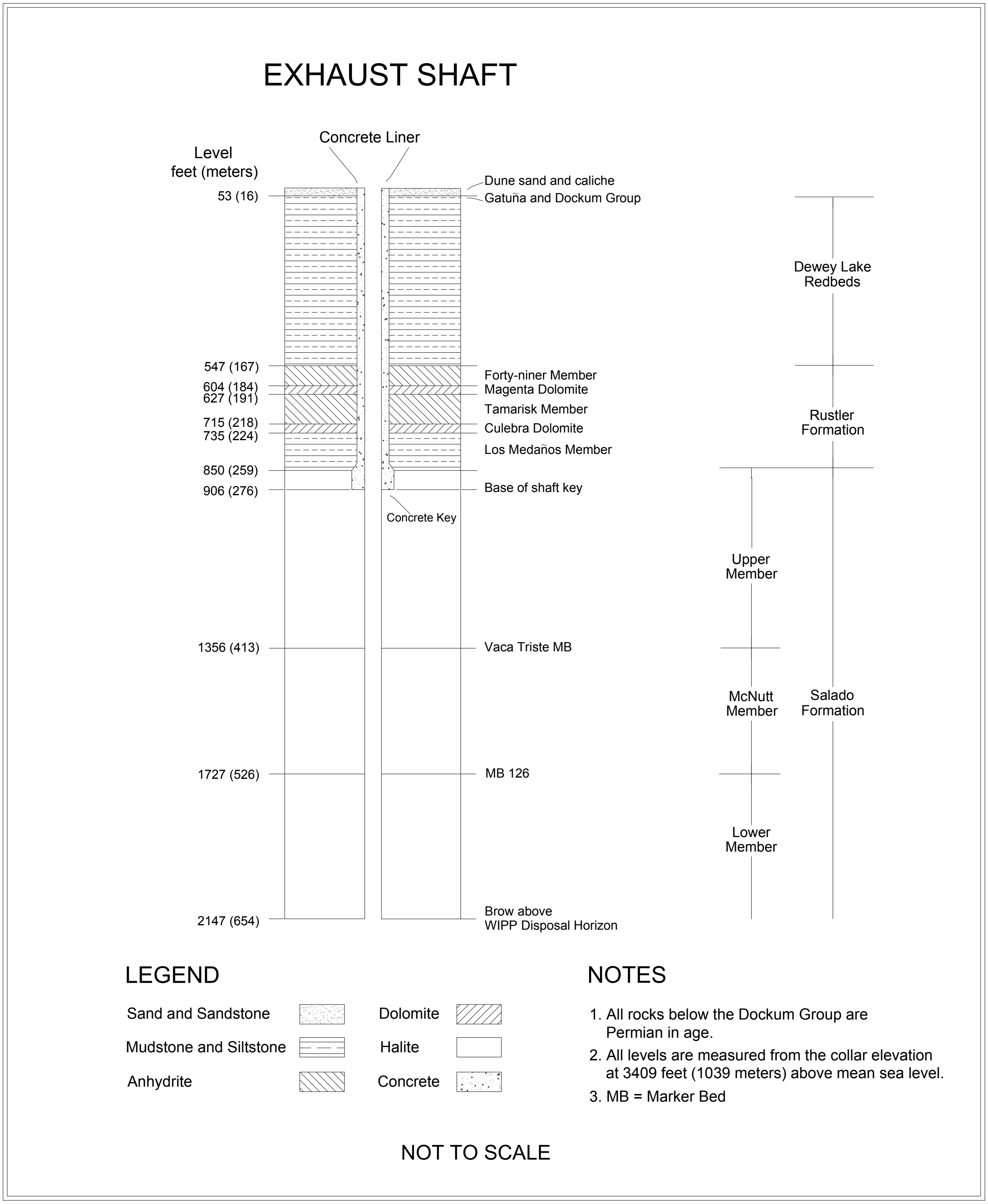

Figure 3-7 Exhaust Shaft Stratigraphy

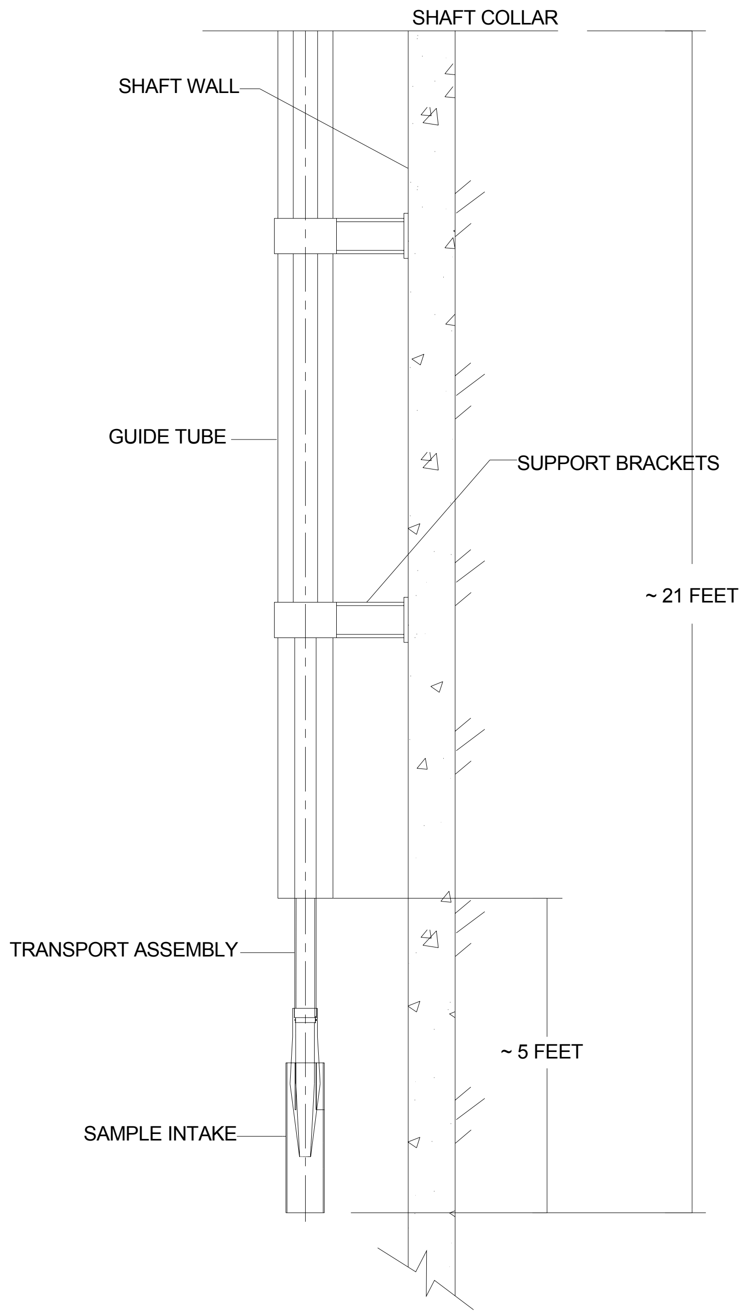

Figure 3-8 Sample Exhaust Shaft Intake Air Monitoring System

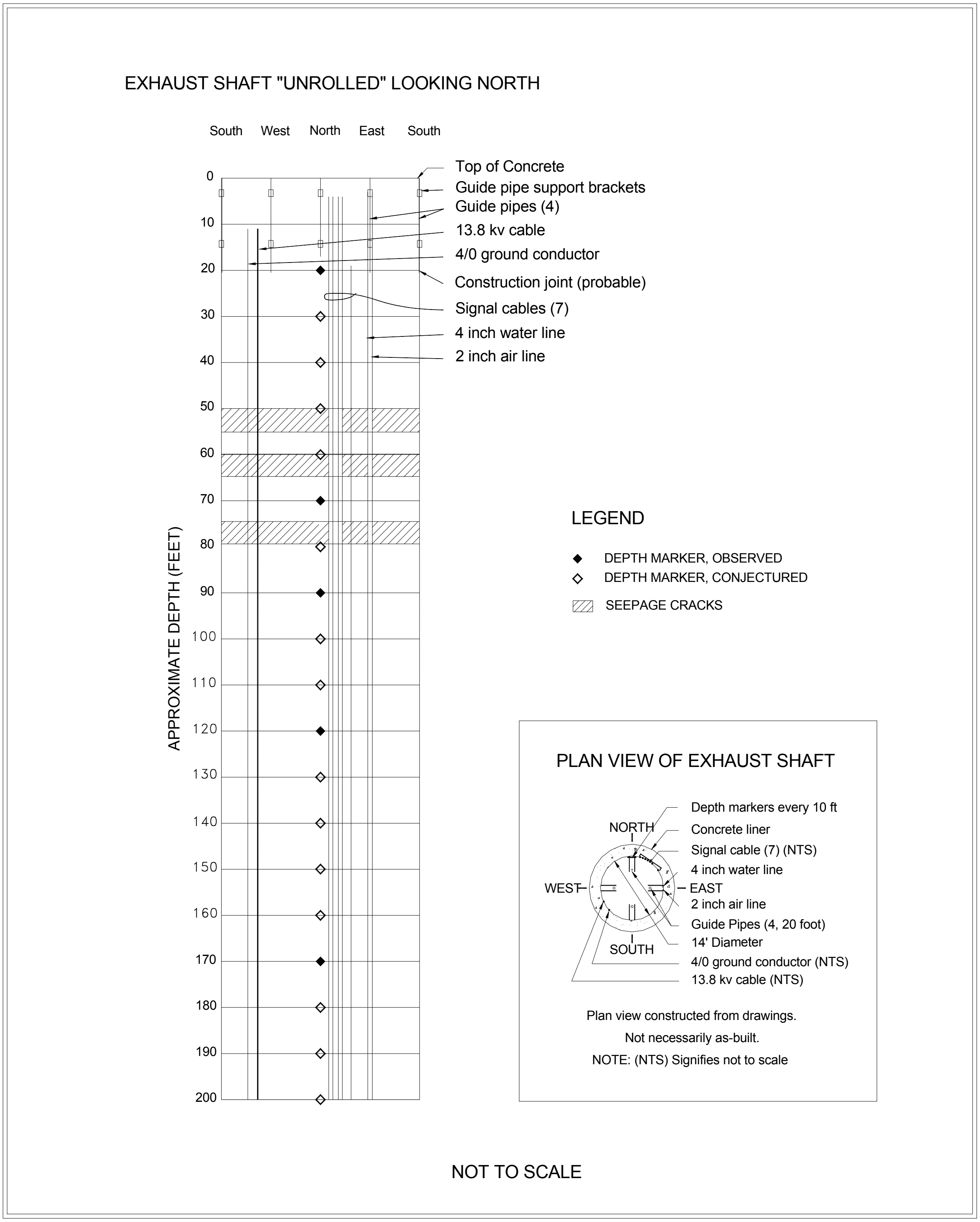

Figure 3-9 Diagram of Exhaust Shaft Fixtures (200 ft Upper Portion)

The shaft walls were examined for cracks, moisture, and encrustation, with particular attention paid to three water rings located at the base of the Magenta and Culebra members of the Rustler Formation and the bottom of the shaft key. As noted earlier, the condition of the shaft wall varies depending on the airflow, humidity, temperature, and underground mining activities. During this reporting period, there was significant mining activity in the Panel 3 and in the Northern Access Drifts. The principle areas in the shaft with significant salt buildup were the three water rings located at the Magenta, the Culebra, and the key and along upper portions of the east wall of the shaft generally associated with the support brackets, instrument cables and the air and waterlines.

Though the Magenta and Culebra water rings are encrusted with salt buildup, there does not appear to be any water emanating from the liner or water rings. Most of the seepage was observed along the east face of the shaft wall near the instrumentation cables and the air and waterlines in the upper section of the shaft. Though the presence of water is an inconvenience requiring periodic disposal, at this time it does not appear to have created any hazard or compromised the structural integrity of the shaft. However, the presence of brine increases the probability of corrosion and deterioration of utility hangers and brackets. There are no visible signs of dissolution of the salt below the key.

The video inspection also concentrated on the installed utilities and support brackets. This included the 13.8 kilovolt amp (kVA) power cable and the grounding cable located on the west wall of the shaft, the instrumentation cables located on the northeast wall of the shaft, and the 4-in. airline and the 2-in. water line located on the east wall of the shaft. Video inspection of the 13.8 kVA cable and the grounding cable show no visible signs of damage. There is sporadic salt buildup on the cables. Currently, long-term implications of salt buildup on the cables are unknown. The 4-in. compressed air line and the 2-in. water line extend from the ground surface to the bottom of the shaft. At present, neither line is being used. Inspection of the integrity of the brackets holding the air line and water line is difficult to assess because of salt buildup. However, there does not appear to be any indication that the brackets, which hold the air line and water line in place, are broken. Currently seventeen instrumentation cable breaks were observed in the shaft. However, the majority of these cable breaks are associated with abandoned cables, and therefore should have minimal impact on shaft monitoring or shaft operations.

Table 3-1 Water Removed from the Exhaust Shaft Catch Basin

July 1997 – June 1998		July 1998 – June 1999		July 1999 – June 2000		July 2000 – June 2001		July 2001 – June 2002		July 2002 – June 2003	
Date	**Gallons**	**Date**	**Gallons**	**Date**	**Gallons**	**Date**	**Gallons**	**Date**	**Gallons**	**Date**	**Gallons**
7/18/97	275	7/1/98	770	7/19/99	110	7/3/00	220	7/31/01	165	07/02/2002	165
7/28/97	660	7/7/98	330	12/13/99	165	7/15/00	110	8/21/01	1595	07/08/2002	440
8/1//97	550	7/14/98	220	2/21/00	110	9/18/00	330	9/13/01	330	07/09/2002	495
8/4/97	715	7/16/98	275	5/16/00	715	10/24/00	110	10/15/01	770	07/10/2002	660
8/8/97	770	7/23/98	165	6/7/00	165	3/7/01	110	10/30/01	220	07/30/2002	220
8/11/97	660	7/24/98	220	6/12/00	275	3/21/01	165	4/29/02	275	09/17/2002	165
8/15/97	475	7/27/98	825	6/19/00	440	4/10/01	220	6/11/02	550	09/24/2003	Sludge 330
8/18/97	330	7/28/98	330	6/22/00	330	4/17/01	220	6/22/02	330	03/25/2003	Sludge 220
8/22/97	330	8/3/98	495	6/30/00	165	4/24/01	110	**Total**	**4235**	05/27/2003	55
8/25/97	1045	8/10/98	1265	**Total**	**2475**	5/22/01	110			06/03/2003	220
8/25/97	Sludge 110	8/21/98	330			5/22/01	Sludge 440			06/25/2003	330
9/2/97	220	8/24/98	990			6/12/01	1100			**Total**	**3300**
9/15/97	605	8/27/98	1155			6/13/01	110				
9/22/97	550	9/1/98	330			Sludge	110				
10/13/97	825	10/5/98	385			**Total**	**3465**				
10/20/97	220	10/26/98	660								
11/3/97	275	11/23/98	110								
11/10/97	385	2/1/99	385								
11/17/97	385	2/10/99	110								
11/24/97	330	5/4/99	330								
12/10/97	440	5/11/99	110								
12/12/97	550	5/24/99	605								
1/2/98	220	5/26/99	165								
1/12/98	605	6/1/99	165								
2/2/98	660	6/4/99	165								
2/16/98	605	6/10/99	165								
3/16/98	605	6/10/99	Sludge 165								
5/4/98	660	6/16/99	165								
5/11/98	550	6/21/99	1705								
5/18/98	495	6/23/99	275								
5/20/98	110	6/30/99	605								
6/1/98	330	**Total**	**14135**								
6/10/98	90										
6/15/98	385										
6/22/98	165										
Total	**16185**										

Table 3-1 Continued

Water Removed from the Exhaust Shaft Catch Basin

July 2003 – June 2004		July 2004 – June 2005		July2005 – June 2006		July 2006 – June 2007		July 2007 – June 2008		July 2008 – June 2009	
Date	**Gallons**										
3/25/03	Sludge 220										
5/27/03	55										
6/3/03	220										
6/25/03	330										
7/8/03	605										
7/9/03	550										
7/17/03	165										
8/12/03	275										
10/14/03	165										
10/20/03	440										
10/21/03	330										
11/21/03	220										
11/21/03	Sludge 660										
Total	**4015**										

3.3.2 Instrumentation

The Exhaust Shaft was equipped with geomechanical instrumentation in two stages. Earth pressure cells were installed behind the liner key in November 1984. Piezometers and nine multiposition borehole extensometers were installed during November and December 1985. Figures 3-10 and 3-11 illustrate the instrumentation configuration.

The extensometers at the 1,573-ft (480-m) level indicate annual collar displacement rates ranging from 0.01 to 0.02 in/yr. (0.03 to 0.04 cm/yr.) These rates indicate that the rates are decreasing from the previous reporting period. At the 2,066-ft (630-m) level, the annualized collar displacement rate was 0.07 in/yr (0.19 cm/yr) from the one functioning extensometer. These displacements indicate continued deformation into the shaft; however, there is no indication of accelerated movement. Table 3-2 summarizes information regarding collar displacement measurements from these extensometers.

Table 3-2 Collar Displacement at the Exhaust Shaft Extensometers

Field Tag	Location Shaft Level	Date Last Reading	Collar Displacement Relative to Deepest Anchor in. (cm)	Displacement Rate 2003 to 2004 in/yr (cm/yr)	Displacement Rate 2002 to 2003 in/yr (cm/yr)	Rate Change Percent[a]	Comments
35X-GE-00204	1573	06/01/04	0.378 (0.960)	0.01 (0.03)	0.02 (0.04)	-19%	
35X-GE-00205	1573	06/01/04	0.396 (1.006)	0.02 (0.04)	0.02 (0.04)	-12%	
35X-GE-00206	1573	06/01/04	0.409 (1.039)	0.02 (0.04)	0.02 (0.04)	-21%	
35X-GE-00207	2066	06/01/04	1.831 (4.651)	0.07 (0.19)	0.07 (0.18)	1%	

in./yr = inch(es) per year.
cm/yr = centimeter(s) per year.
[a] Rate change is calculated from the difference between the 2003–2004 rate and the 2002–2003 rate.

Eleven of the 21 piezometers remain in working condition. The fluid pressure readings from the working piezometers at the end of the reporting period range from -2.2 psi (-15.2 kPa) at the 544-ft (166-m) level to 141 psi (972 kPa) at the 721-ft (220-m) level. Maximum pressure readings from the working piezometers during this reporting period were consistent with maximum readings from the previous reporting period with some of the recorded pressures having decreased slightly.

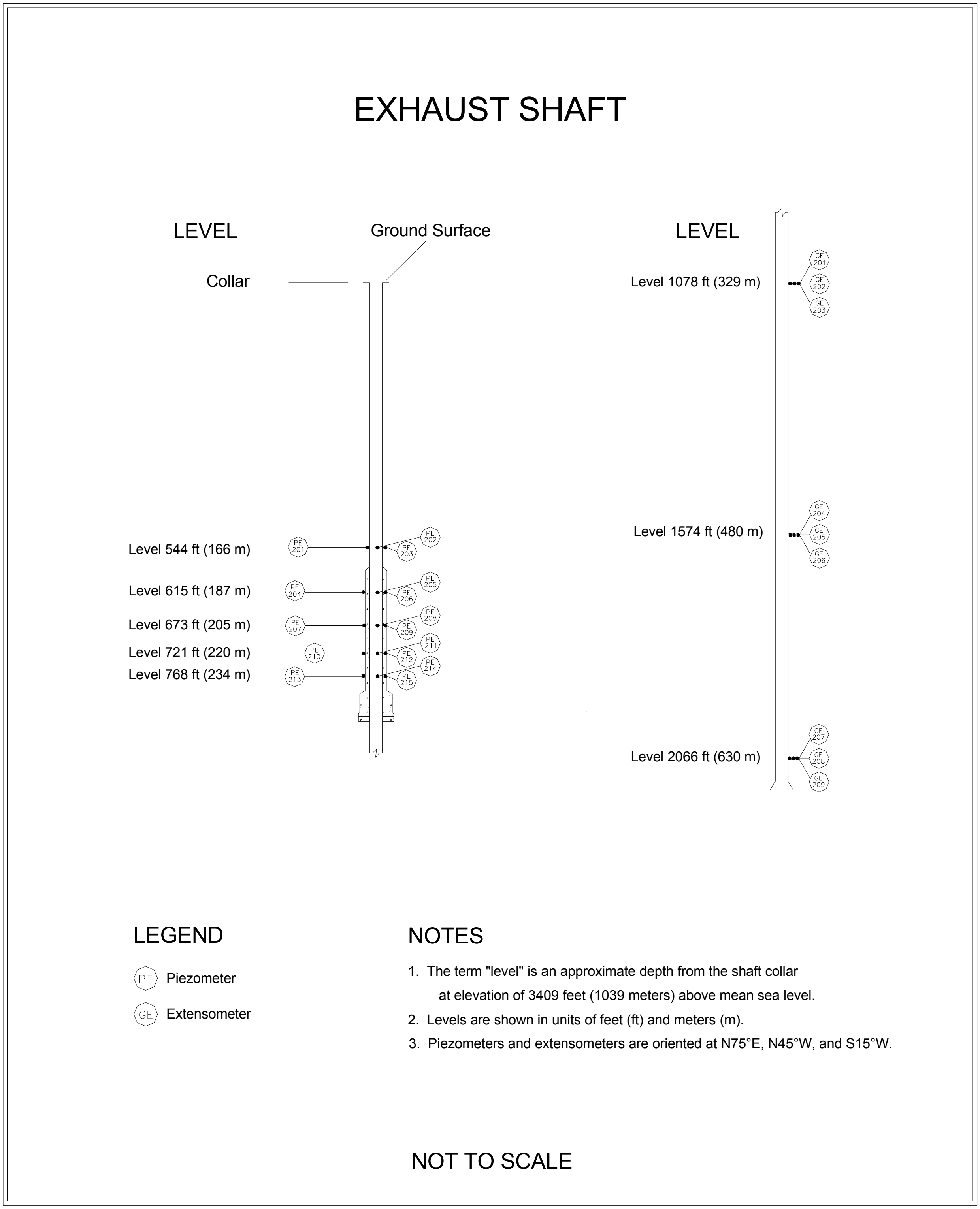

Figure 3-10 Exhaust Shaft Instrumentation (Without Shaft Key)

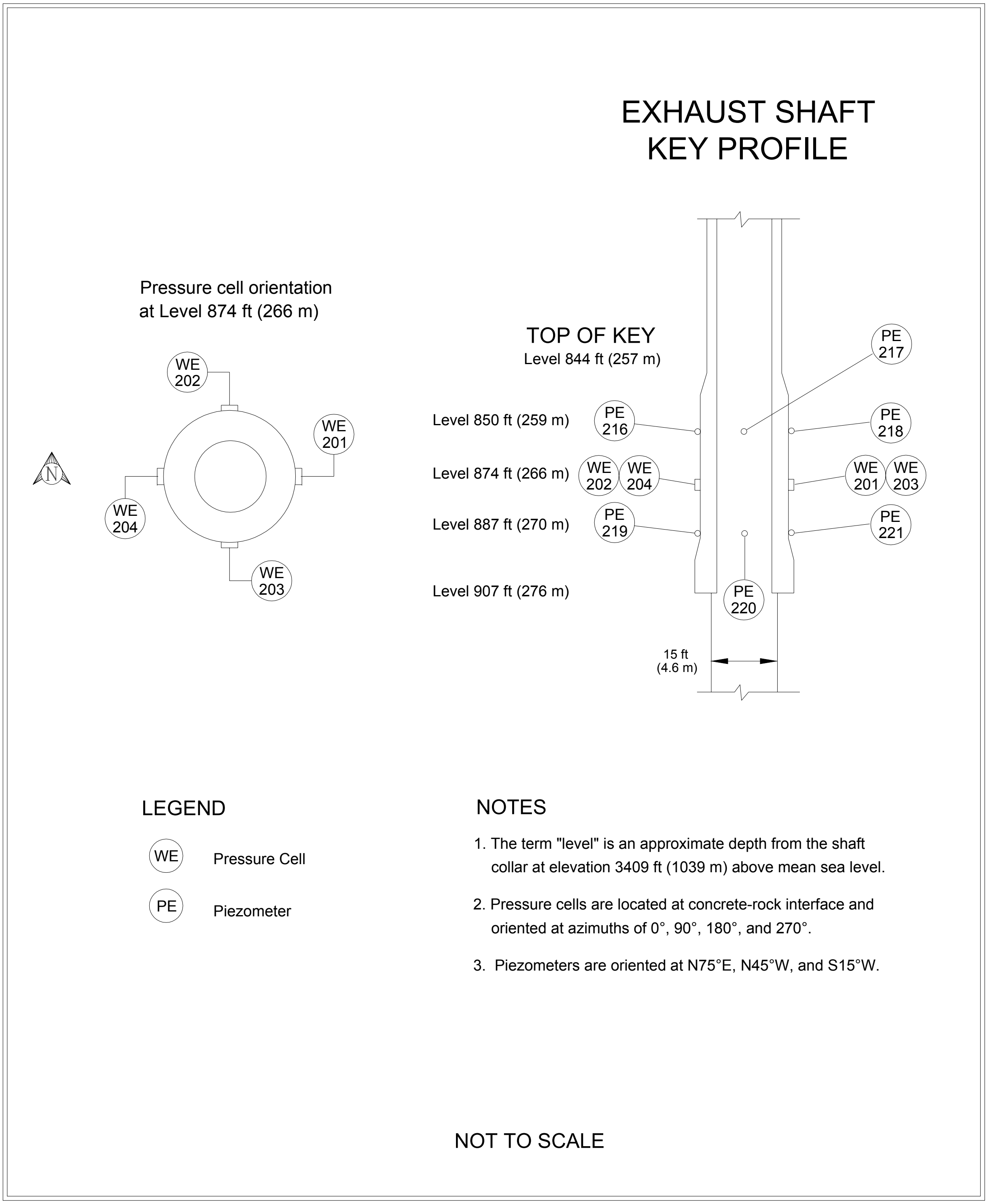

Figure 3-11 Exhaust Shaft Key Instrumentation

Four earth pressure cells were installed in the key section of the Exhaust Shaft during concrete emplacement. Currently, only two of these earth pressure cells are functional. During this reporting period, the pressure cell readings indicated changes of 0.7 and 1.9 psi. The peak recorded pressures during this period are 55.1 and 44.3 psi (380 and 305 kPa).

3.4 Air Intake Shaft

The Air Intake Shaft was drilled from December 4, 1987, to August 31, 1988, to establish a primary route for surface air to enter the repository (see Figure 1-2). Stratigraphic mapping was conducted from September 14, 1988, to November 14, 1989 (Holt and Powers, 1990). Figure 3-12 illustrates the Air Intake Shaft stratigraphy.

The Air Intake Shaft is lined with nonreinforced concrete from the surface to the bottom of the shaft key at a depth of 903 ft (275 m). The Air Intake Shaft key is 81 ft (25 m) long with an inside diameter of 16 ft (5 m). The diameter below the shaft key is 20 ft (6 m), and the shaft is unlined below the key to the facility horizon at a depth of 2,150 ft (655 m). The shaft walls are bolted and meshed from just below the key all the way down to the shaft station. The Air Intake Shaft has no sump.

3.4.1 Shaft Performance

Weekly visual inspections were performed on the Air Intake Shaft during this reporting period and the shaft was found to be in satisfactory condition. No ground control activities other than routine maintenance were required during this reporting period.

3.4.2 Instrumentation

Sandia National Laboratories/New Mexico (SNL/NM) installed geomechanical instruments in the Air Intake Shaft in 1988. WTS maintains responsibility for the operation of all of the instruments located in the Air Intake Shaft as well as for data acquisition and instrument maintenance. WTS provides the data to SNL/NM for analysis. Data from these instruments are available from SNL/NM by request.

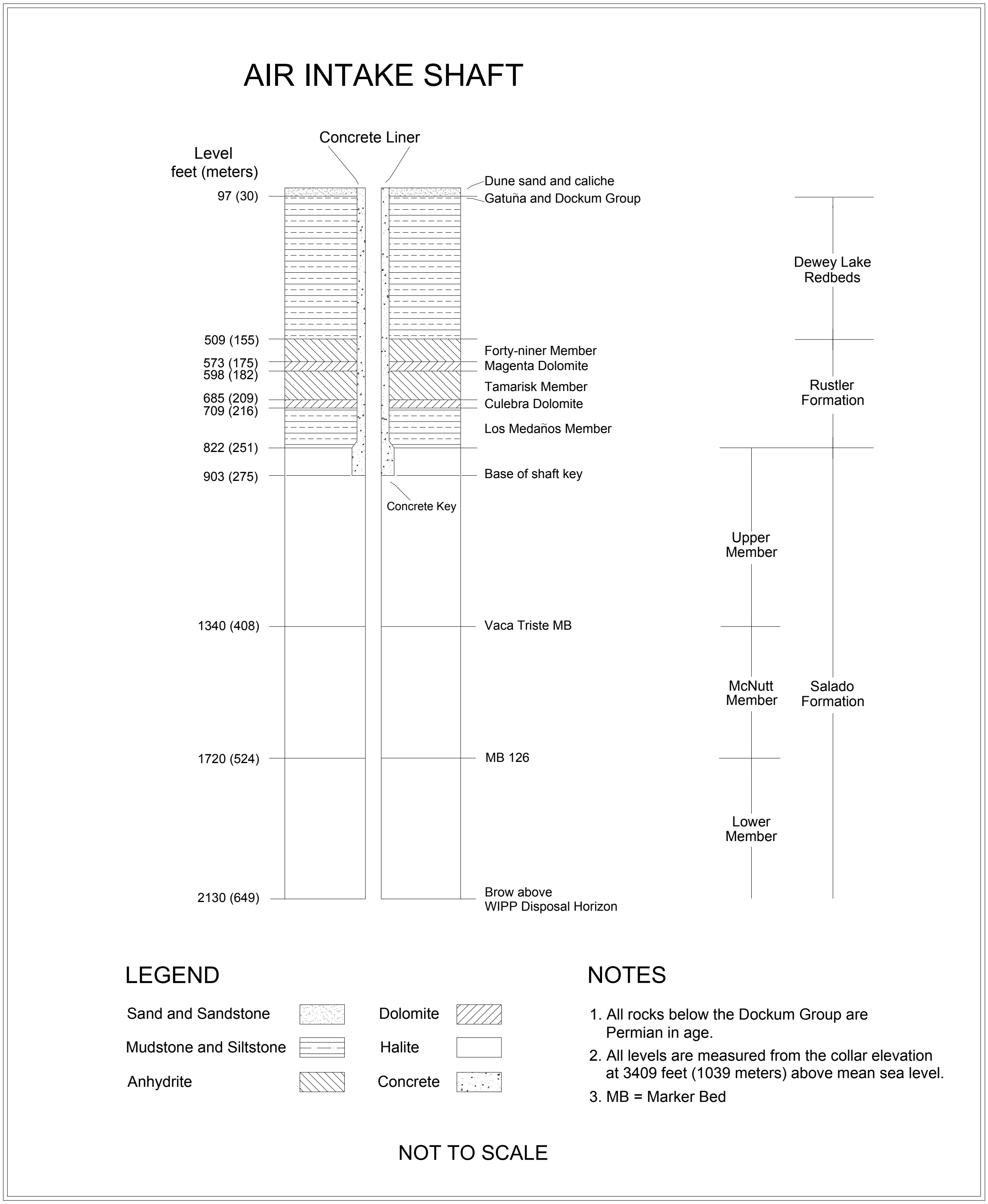

Figure 3-12 Air Intake Shaft Stratigraphy

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4.0 Performance of Shaft Stations

This chapter describes the instrumentation and geomechanical performance of the shaft stations at the base of the Salt Handling Shaft, the Waste Shaft, and the Air Intake Shaft. The Exhaust Shaft does not have an enlarged shaft station and, therefore, is not included in this chapter.

4.1 Salt Handling Shaft Station

The Salt Handling Shaft Station was excavated between May 2 and June 3, 1982, by drilling and blasting. In 1987 the station was enlarged, removing the roof beam up to Anhydrite "b" between South 90 and North 20 using a mechanical scaler. In 1995 the remaining roof beam at the north end of the station was also removed up to Anhydrite "b." The station area south of the shaft is 90 ft (27.5 m) long and 32 to 38 ft (10 to 12 m) wide. The height of the station south of the shaft is 18 ft (5.5 m). The station dimensions north of the shaft are approximately 30 ft (9 m) long, 32 to 35 ft (10 to 11 m) wide, and 18 ft (5.5 m) high. The shaft extends approximately 140 ft (43 m) below the facility horizon to accommodate the skip loading equipment and to act as a sump. Figure 4-1 shows a generalized cross section of the station.

4.1.1 Modifications to Excavation and Ground Control Activities

No major modifications were performed in the Salt Handling Station during this reporting period. Ground control was performed as routine maintenance.

4.1.2 Instrumentation

Geomechanical instrumentation was installed in the Salt Handling Shaft Station between June 1982 and February 1983, with subsequent reinstallation of extensometers and convergence points as necessary. Figure 4-2 shows the instrument locations after the roof beam was taken down.

There were three extensometers located in the Salt Handling Shaft Station. Due to instrument malfunctions and the removal of one extensometer during roof removal, there are no extensometer data for the Salt Handling Shaft Station for this reporting period; however, historical data are maintained for comparative purposes. Four vertical convergence point arrays are currently monitored. Table 4-1 summarizes the vertical closure rates in the Salt Handling Shaft Station from July 2003 through June 2004. Salt

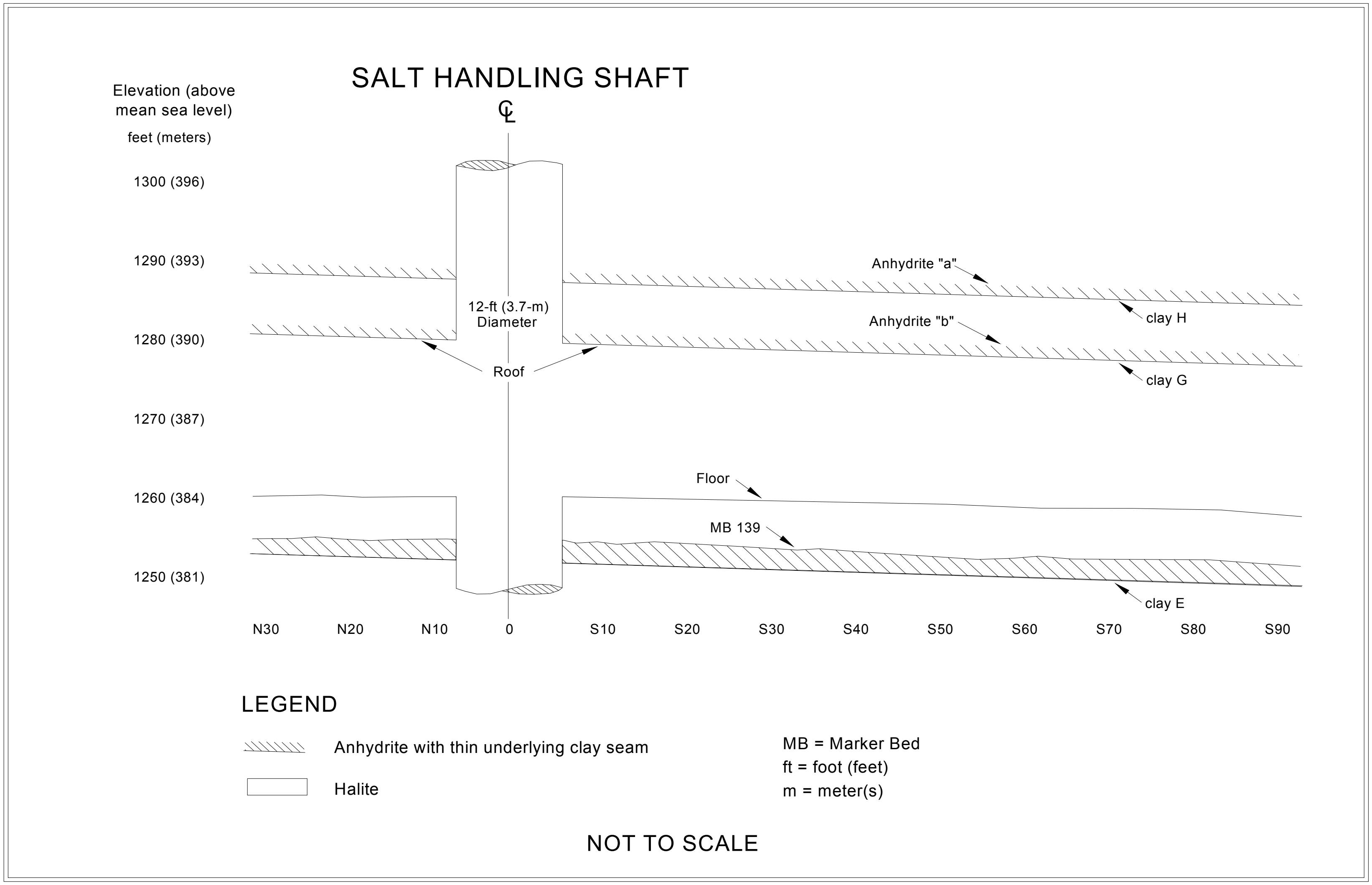

Figure 4-1 Salt Handling Shaft Station Stratigraphy

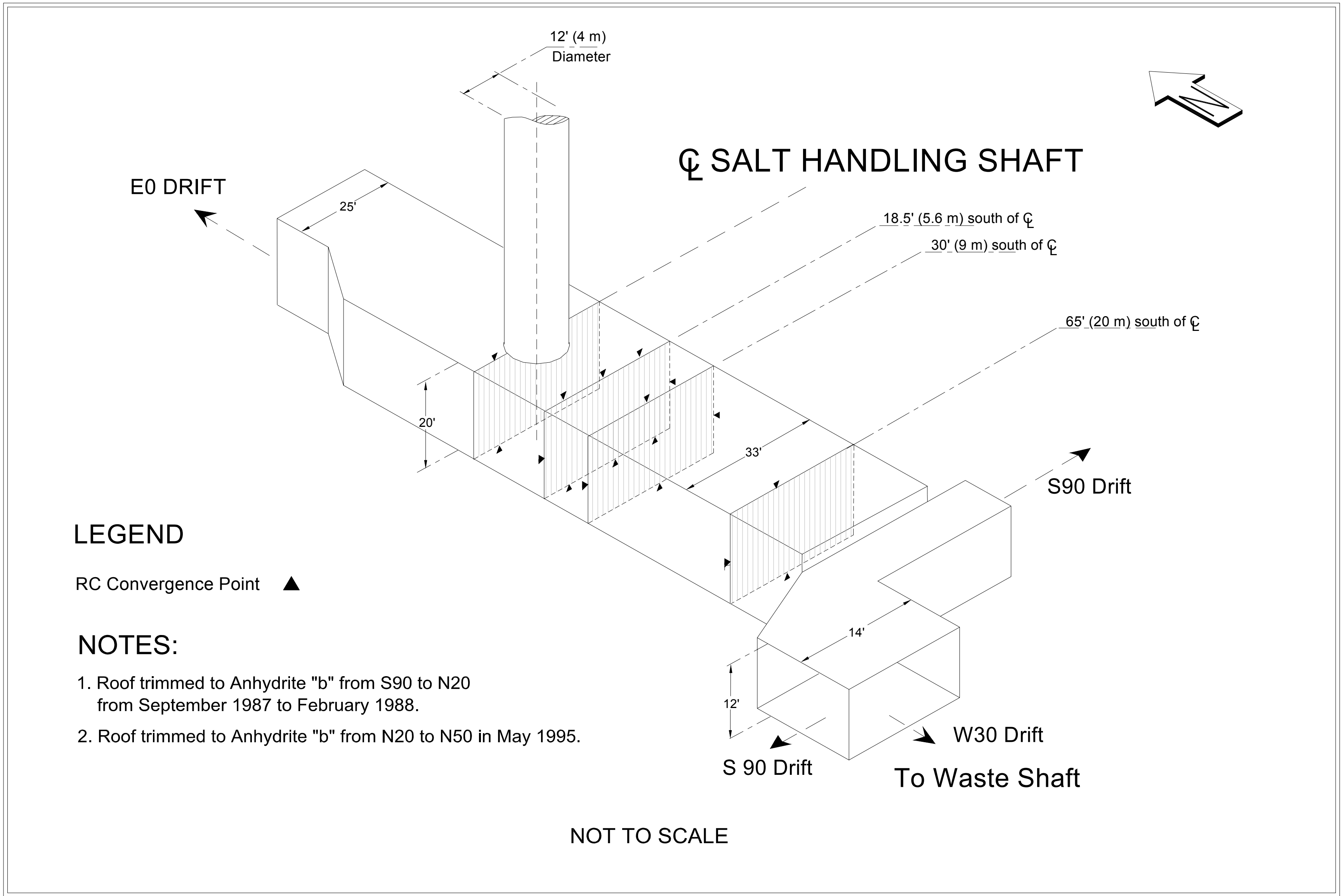

Figure 4-2 Salt Handling Shaft Station Instrumentation After Roof Beam Excavation

Handling Shaft Station vertical closure rates indicate that the rates are decreasing compared to previous reporting periods.

Table 4-1 Vertical Closure Rates in the Salt Handling Shaft Station

Location	Chord*	Last Reading	Total Cumulative Displacement Inches/(cm.)	Closure Rate 2003 to 2004 in./yr (cm/yr)	Closure Rate 2002 to 2003 in./yr (cm/yr)	Rate Change Percent[a]	Comments
E0, W12	A-C	06/03/04	17.815 (45.250)	0.73 (1.85)	0.83 (2.11)	-12%	
E0, S18	A-E	06/03/04	26.235 (66.637)	1.39 (3.53)	1.57 (4.00)	-12%	
E0, S18	B-D	06/03/04	26.425 (67.120)	1.50 (3.80)	1.83 (4.65)	-18%	
E0, S18	F-H	06/03/04	16.789 (42.644)	0.96 (2.44)	1.10 (2.80)	-13%	
E0, S30	A-C	06/03/04	40.703 (103.386)	1.47 (3.74)	1.65 (4.20)	-11%	
E0, S65	A-C	06/03/04	37.114 (94.270)	1.08 (2.73)	1.24 (3.14)	-13%	

in./yr = inch(es) per year.
cm/yr = centimeter(s) per year.
*Chord is defined in "Geotechnical Analysis Report for July 2003–June 2004 Supporting Data."
[a] Increase in convergence rate is calculated from the difference between the 2003–2004 rate and the 2002–2003 rate.

4.2 Waste Shaft Station

The Waste Shaft Station was initially excavated with a continuous miner as a ventilation connection to a 6-ft (2-m) diameter exhaust shaft in November 1982. In 1984, the station was enlarged to a height of 15 to 20 ft (4.5 to 6 m) and a width of 20 to 30 ft (6 to 9 m). The station is approximately 150 ft (46 m) long. In 1988, the station walls were trimmed and concrete was placed on the floor. Since 1988, the Waste Shaft Station has undergone three major floor renovations. A 53-ft (16-m)-long section of the reinforced concrete was removed in February 1991, in 1995 an additional 30-ft (9-m) section was removed, and in 2000 the most recent floor maintenance included trimming of the floor and reinstallation of the rails supported by segmented concrete panels on a crushed rock backfill. Figure 4-3 shows a cross section of the Waste Shaft Station.

4.2.1 Modifications to Excavation and Ground Control Activities

During this reporting period, the Waste Shaft Station was pattern bolted using threaded bar bolts and mats. Other ground control activities performed at the Waste Shaft Station during this reporting period consisted of routine rib maintenance and the routine replacement of failed rock bolts.

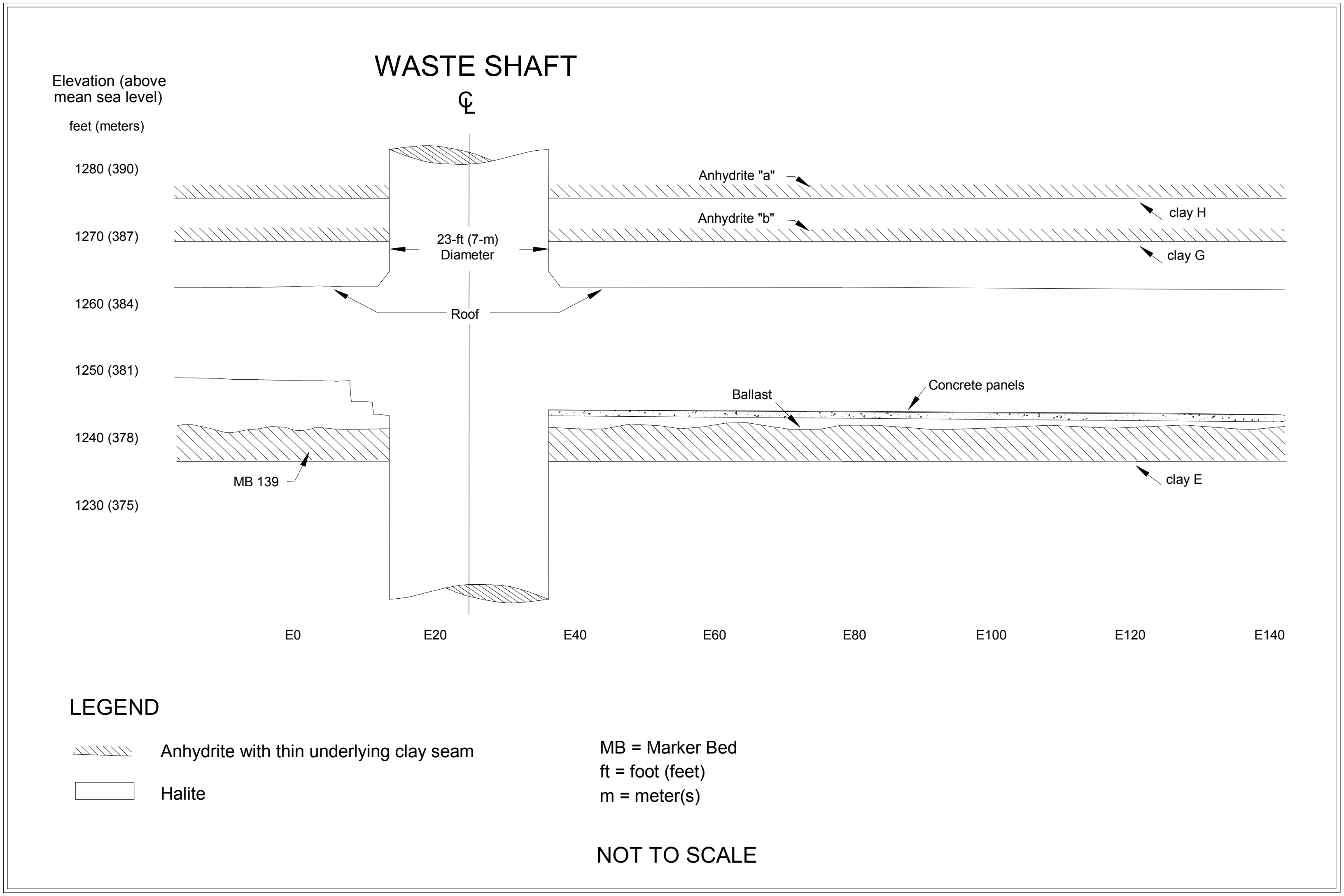

Figure 4-3 Waste Shaft Station Stratigraphy

4.2.2 Instrumentation

Instruments were initially installed in the Waste Shaft Station between November 12 and December 2, 1982. Figure 4-4 illustrates the locations after enlargement. There are five extensometers in the roof of the Waste Shaft Station (located at West 30 and East 140) that are currently being monitored. In addition, horizontal convergence is being monitored at East 30 and East 90.

Table 4-2 summarizes the recent history of the roof extensometers in the Waste Shaft Station. The extensometers, 51X-GE-00268 (West 30) and 51X-GE-00279 (East 140), remain in working condition. However, due to transducer malfunctions, there are no reliable readings for 51X-GE-00279. There were three new extensometers installed during this reporting period. Extensometers 51X-GE-00356 and 51X-GE-00357 were installed in the shaft brow and 51X-GE-01025 was installed at East 87.

Table 4-2 Summary of Roof Extensometers in Waste Shaft Station

Instrument	Location	Last Reading	Collar Displacement Relative to Deepest Anchor in. (cm)	Displacement Rate 2003 to 2004 in./yr (cm/yr)	Displacement Rate 2002 to 2003 in./yr (cm/yr)	Rate Change Percent [a]	Comments
51X-GE-00268	S400, W30	6/30/2004	8.517 (21.633)	0.65 (1.65)	N/A	N/A	Insufficient data
51X-GE-00356	Waste Shaft Brow	6/28/2004	0.029 (0.074)	0.05 (0.12)	N/A	N/A	New Installation
51X-GE-00357	Waste Shaft Brow	6/28/2004	0.080 (0.203)	0.13 (0.33)	N/A	N/A	New Installation
51X-GE-01025	S400, E87	6/29/2004	0.237 (0.602)	0.53 (1.34)	N/A	N/A	New Installation
51X-GE-00279	S400, E140	5/17/2004	11.702 (29.723)	N/A	0.66 (1.68)	N/A	Transducer Malfunction

in./yr = inch(es) per year.
cm/yr = centimeter(s) per year.
[a] Rate change is calculated from the difference between the 2003-2004 rate and the 2002-2003 rate.

Table 4-3 summarizes the annual horizontal closure rates calculated from convergence point data for this reporting period. The data indicate a slight decrease in the horizontal closure rate at East 30 of -2.0 percent and a slight increase at East 90 of 1.0 percent, respectively, relative to the previous annual closure rates.

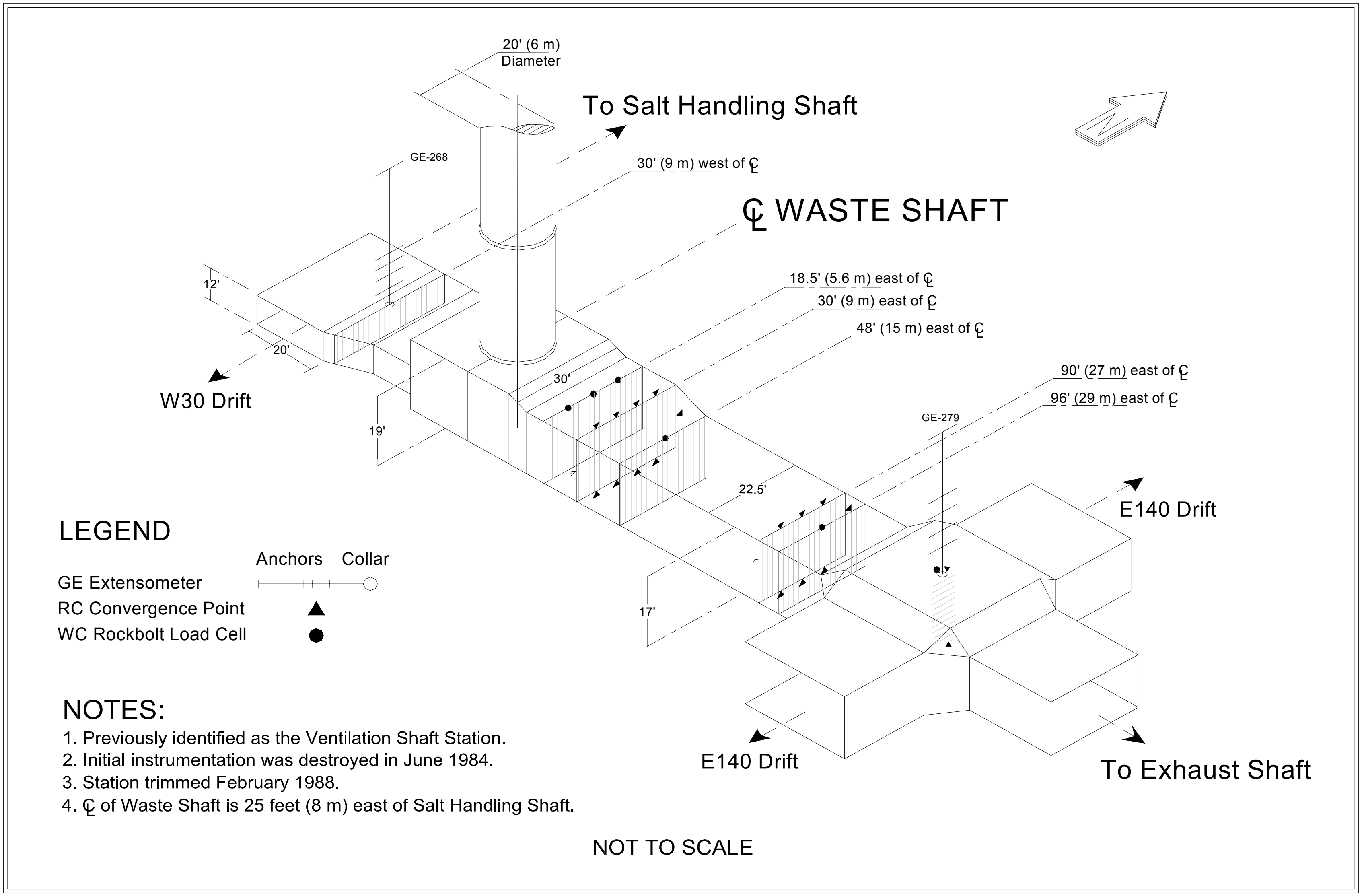

Figure 4-4 Waste Shaft Station Instrumentation After Wall Trimming

Eighteen rock bolt load cells are installed in the roof and brow of the Waste Shaft Station. The loads on 12 of these rock bolt load cells are monitored regularly. During this reporting period, threaded bar bolts and mats were installed in the Waste Shaft Station. Load cells were installed at E40 and E80 to monitor loading of this support system.

Table 4-3 Horizontal Closure Rates in the Waste Shaft Station

Location	Chord*	Last Reading	Total Cumulative Displacement Inches/(cm.)	Closure Rate 2003 to 2004 in./yr (cm/yr)	Closure Rate 2002 to 2003 in./yr (cm/yr)	Rate Change Percent [a]	Comments
S400, E30	C-H	6/16/2004	16.727 (42.487)	0.84 (2.13)	0.86 (2.17)	-2%	
S400, E90	C-G	6/16/2004	19.126 (48.580)	0.97 (2.46)	0.96 (2.43)	1%	

in./yr = inch(es) per year.
cm/yr = centimeter(s) per year.
*Chord is defined in "Geotechnical Analysis Report for July 2003–June 2004 Supporting Data."
[a] Increase in convergence rate is calculated from the difference between the 2003–2004 rate and the 2002–2003 rate.

4.3 Air Intake Shaft Station

The Air Intake Shaft Station was excavated in late 1987 and early 1988 using a continuous miner. The Air Intake Shaft typically is not used to transport personnel or materials between the surface and the underground, but does have a work platform that can be raised and lowered in the shaft to perform routine ground maintenance. There is minimal operational activity at the Air Intake Shaft Station.

4.3.1 Modifications to Excavation and Ground Control Activities

During this reporting period, the Air Intake Shaft Station brows were pattern bolted using threaded bar bolts and mats. Routine maintenance and inspections were also performed at the Air Intake Shaft Station during this reporting period.

4.3.2 Instrumentation

Convergence point and extensometer instrumentation located near the Air Intake Shaft Station are presented in Chapter 5.0 as part of the discussion on the performance of the access drifts. Twenty rock bolt load cells installed in the Air Intake Shaft Station area are monitored regularly.

5.0 Performance of Access Drifts

This chapter describes the geomechanical performance of the central underground access drifts. The Waste Disposal Area is discussed in Chapter 6.0. There are four major north-south drifts in the WIPP underground, intersected by shorter east-west cross-drifts. These drift dimensions range from 8 ft (2.4 m) to 21 ft (6.4 m) in height and from 14 ft (4.3 m) to 33 ft (9.2 m) in width.

5.1 Modifications to Excavation and Ground Control Activities

Three of the four major north-south access drifts were extended towards the south during this reporting period. E-140 was mined to S3650 in 1983. Trimming, scaling, and floor milling activities were performed as necessary in many areas throughout the WIPP underground. Table 5-1 summarizes these activities. Table 5-1 also summarizes ground control activities (e.g., rock bolting and installing wire mesh) performed in various locations in the access drifts.

5.2 Instrumentation

This section discusses instrumentation details and locations for each instrumentation type.

5.2.1 Borehole Extensometers

Three new extensometers were installed during this reporting period. These borehole extensometers were installed in E0 and E140. All operating underground extensometers continue to be monitored. Five borehole extensometers were damaged or mined out during this reporting period. Fifty-one borehole extensometers continue to be monitored.

5.2.2 Convergence Points

Figure 5-1 shows typical convergence point array configurations. Instrumentation installed during this reporting period was limited to the installation and replacement of convergence point arrays and the installation of new monitoring arrays in the newly mined areas. There were twenty new and replaced convergence points at various locations throughout the WIPP underground access drifts where rib, roof, or floor trimming activities had been performed during this and the previous reporting periods. Horizontal and vertical convergence point arrays were installed at various locations. The majority of these installations were located in the East 0, East 140, and the southern cross-drifts. Convergence points within the access drifts are read manually at least every two months, with more frequent monitoring in some areas. Table 5-2 lists the new and replacement convergence points that were installed during this reporting period.

Table 5-1 Summary of Modifications and Ground Control Activities in the Access Drifts July 1, 2003, through June 30, 2004

Location	Work Performed
N215 and N300	pattern bolted/ threaded bar bolts and mesh
N300, E0 to the W620	trimmed floor
N460, E0 to E140	pattern bolted/ mechanical bolts and mesh
N1100 and N1400, E0 to E140	pattern bolted/ mechanical bolts and mesh
N1100 and N1400, E0 to E140	trimmed ribs
S90 from W170 to Room Q	trimmed floor
S700, E140 and E300	trimmed ribs and floor
S1000, W170 to W30	trimmed roof, ribs and floor. pattern bolted/ mechanical bolts and mesh
S1300 Oil Bay	pattern bolted/ mechanical bolts and mesh
S2520, W170 to W30	pattern bolted/ mechanical bolts and mesh
S2750, E300 to W170	pattern bolted/ mechanical bolts and mesh
S3080, E300 to W170	cut to final dimension, pattern bolted/ mechanical bolts and mesh
S3310, E300 to W170	cut to final dimension, pattern bolted/ mechanical bolts and mesh
E300, W30, and W170, S3310 to S3650	Initial mining
E300, S3080 to S3310	pattern bolted/ mechanical bolts and mesh
E140, S1000 to S1300	pattern bolted/ mechanical bolts and mesh
E140 and E0, N460 to N1400	trimmed rib and floor
E140, N460 to N1100	pattern bolted/ mechanical bolts and mesh
E140, S1920 to S3080	pattern bolted/mechanical and threaded bar bolts, mats and mesh
E140, S1550 and S1775	supplemental bolting threaded bar bolts and mats
E140, S1920 to S3080	pattern bolted/mechanical and threaded bar bolts, mats and mesh
E140, S2750 to S3080	trimmed floor
E140, S3080 to S3310	pattern bolted/ mechanical bolts and mesh
E140, S3310 to S3650	re-entry and salt removal
E0, N460 to N1400	pattern bolted/ mechanical bolts and mesh
W30, S3080 to S3310	cut to final dimension
W30, S90 to S700	pattern bolted/ mechanical bolts and mesh
W30, S2520 to S3080	pattern bolted/ mechanical bolts and mesh
W170, S2520 to S3310	pattern bolted/ mechanical bolts and mesh

Table 5-2 New and Replaced Convergence Points Installed in the Access Drifts July 1, 2003, through June 30, 2004

Location	N/R	Field Tag#	Chord*	Date Installed
E0, N300	R	E0-N300-5	A-C (Vertical)	5/6/2004
E0, N780	R	E0-N780-2	A-C (Vertical)	10/2/2003
E0, N940	R	E0-N940-4	A-C (Vertical)	10/2/2003
E0, N1100	R	E0-N1100-4	A-C (Vertical)	10/2/2003
E0, N1266	R	E0-N1266-4	A-C (Vertical)	10/2/2003
E140, N150	R	E140-N150-2	A-C (Vertical)	10/15/2003
E140, N150	R	E140-N150-3	A-C (Vertical)	4/21/2004
E140, N220	R	E140-N220-2	A-C (Vertical)	10/15/2003
E140, S1534	R	E140-S1534-3	B-D (Horizontal)	12/3/2003
E140, S1775	R	E140-S1775-3	B-F (Vertical)	3/19/2004
E140, S2007	R	E140-S2007-4	A-C (Vertical)	3/19/2004
E300, N170	R	E300-N170-2	C-G (Horizontal)	4/21/2004
N215, W500	R	N215-W500-2	A-C (Vertical)	3/18/2004
N300, W170	R	N300-W170-2	A-C (Vertical)	3/18/2004
S90, W905	N	S90-W905	A-C (Vertical)	5/6/2004
S700, E55	N	S700-E55	A-C (Vertical)	5/6/2004
S700, E55	N	S700-E55	B-D (Horizontal)	5/6/2004
S1000, W98	R	S1000-W98-2	A-C (Vertical)	3/18/2004
S1000, W98	R	S1000-W98-2	B-D (Horizontal)	3/18/2004
S3080, E55	R	S3080-E55-2	B-D (Horizontal)	1/15/2004

N = New installation.
R = Replacement installation (i.e., instrument replaces older instrument that has failed or has been mined out).
#Field tag chords are defined in "Geotechnical Analysis Report for July 2003–June 2004 Supporting Data"
*Chord configuration is defined in "Geotechnical Analysis Report for July 2003–June 2004 Supporting Data."

5.3 Analysis of Convergence Point and Extensometer Data

Convergence point data are obtained by measuring the change in distance between fixed points anchored into the rock across an opening, either from rib-to-rib or from roof-to-floor. Extensometer data are obtained by measuring the displacement from the reference head anchor (collar) to each fixed anchor of the extensometer. These measurements are made, at a minimum, every two months throughout the WIPP underground, with the exception of when convergence points are not accessible. Convergence rates and extensometer displacement rates indicate how an excavation is performing; rates that decrease or are relatively constant typify stable excavations, whereas increasing rates may indicate some type of developing instability or may be the response to nearby mining.

Where possible, annual closure rates were calculated from convergence point array data from the access drifts. A complete tabulation of these convergence point data and

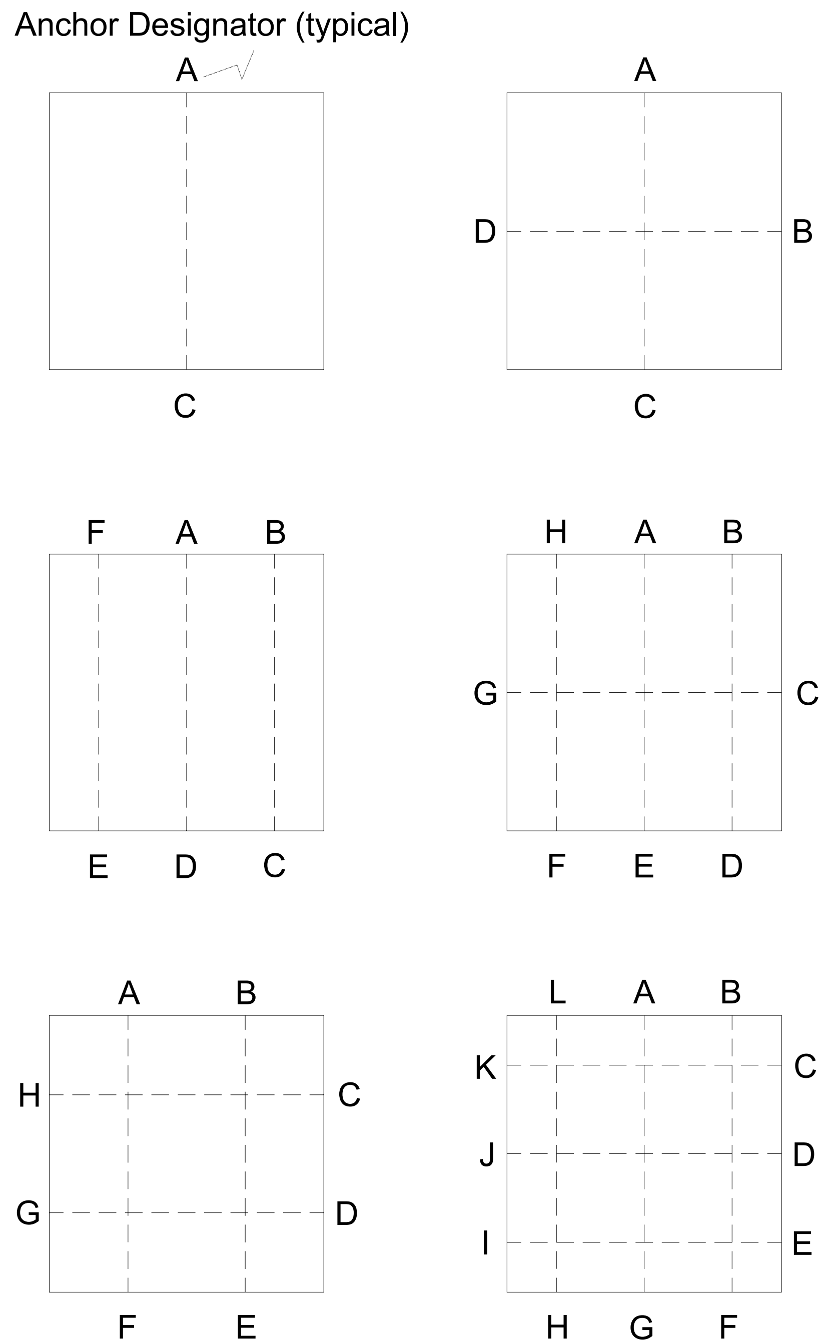

Figure 5-1 Typical Convergence Point Array Configurations Showing Anchor Designations

calculated closure rates are presented in the supporting data document for this report[5]. Locations with increases in annual vertical (Table 5-3) closure rates of greater than 10 percent are shown below.

Routinely, extensometer displacement rates and convergence rates are plotted against time, and comparisons are made through time to identify any acceleration. Annual convergence rates are calculated by determining the difference between the first and last readings of the reporting period and dividing that difference by the time between the two readings (in years). Instruments that indicate acceleration are analyzed to determine the significance of the acceleration. Factors that are considered during the analysis include the magnitude of the respective rates, percentage increase, convergence history, and any recent excavation in the vicinity.

There are 51 active borehole extensometers being monitored at various locations in the access drifts. Of the 51 extensometers, 24 are in the southern East 140 drift to monitor the waste transport route. Where data are available, annual displacement rates were calculated for each of the active extensometers and compared to the annual displacement rates from the previous reporting period. Nine of the extensometers in this area show increased rates; in some cases, this is attributed to lateral displacement. Thirteen of the extensometers in this area show a decreased convergence rate and data was not available on the two other extensometers. The increased movement in the East 140 roof rates may also be attributed to localized fracturing and the effects of anhydrite stringer separations occurring in the roof.

Further analysis of the convergence rate accelerations has shown many of them to be relatively insignificant. Others, such as the southern areas of the access drifts, had closure rate increases that can be directly attributed to continued effects of mining Panel 3 and the associated access drifts.

The rates in East 140, from South 1882 to South 2998, where the roof has been mined to Clay "G," show an increase in the closure rates. These rates are expected to decrease over time as the roof beam removal effect subsides. The rates in West 170, from South 90 to South 1445, show an increase in the closure rates. These rate increases may be attributed to trimming the cross drifts. An example of this trimming is South 1000, West 98 which

[5] Instrumentation data and data plots are presented in "Geotechnical Analysis Report for July 2003–June 2004 Supporting Data." The document is available upon request from the National Technical Information Service. See the back side of this documents cover sheet for details and addresses.

had an increase of 68 percent, where the roof, ribs and floor were trimmed. These rates are expected to decrease over time as the effect of cross drift trimming subsides. Convergence measurements in East 140 between South 1534 and South 1862 show an increasing trend over the long-term median convergence rate. This is due to separations along anhydrite stringers in the roof and localized fracturing. An additional supplemental ground control system was installed in this area to address the separation during this reporting period.

Table 5-3 Increases in Annual Vertical Convergence Rates Greater than 10 Percent in the Access Drifts

Location	Chord*	Last Reading	Total Cumulative Displacement Inches/(cm.)	Closure Rate 2003 to 2004 in./yr (cm/yr)	Closure Rate 2002 to 2003 in./yr (cm/yr)	Rate Change Percent [a]	Comments
E140, S1862	A-E	06/24/04	18.202 (46.233)	3.86 (9.80)	2.94 (7.47)	31%	Anhydrite Stringer
E140, S1862	H-F	06/24/04	10.614 (26.960)	1.75 (4.45)	1.52 (3.86)	15%	Anhydrite Stringer
E140, S2350	A-C	06/23/04	34.064 (86.523)	6.34 (16.10)	4.49 (11.40)	41%	Roof Beam removal
E140, S2425	A-C	06/23/04	15.303 (38.870)	5.21 (13.23)	4.45 (11.30)	17%	Roof Beam removal
E140, S2833	A-C	06/23/04	6.336 (16.093)	4.54 (11.53)	3.41 (8.66)	33%	
E140, S2915	A-C	06/23/04	8.867 (22.522)	6.08 (15.44)	5.53 (14.05)	10%	
E140, S2998	A-C	06/23/04	9.145 (23.228)	6.25 (15.88)	5.68 (14.43)	10%	
N215, W500	A-C	06/24/04	18.891 (47.983)	2.23 (5.66)	1.34 (3.40)	66%	Reinstalled 3/04 Floor Trimming
N300, W170	A-C	06/24/04	22.953 (58.301)	2.75 (6.99)	1.56 (3.96)	76%	Reinstalled 3/04 Floor Trimming
S1000, W98	A-C	06/16/04	19.326 (49.088)	2.46 (6.25)	1.47 (3.73)	68%	Trimming
S1950, E281	A-C	05/12/04	12.783 (32.469)	1.01 (2.57)	0.90 (2.29)	11%	
S1950, E284	A-C	05/12/04	12.875 (32.703)	1.05 (2.67)	0.93 (2.36)	13%	
W170, S90	A-C	06/16/04	9.154 (23.251)	0.96 (2.44)	0.77 (1.96)	24%	Cross drift trimming
W170, S1000	A-C	06/07/04	19.392 (49.256)	1.05 (2.67)	0.70 (1.78)	50%	Cross drift trimming
W170, S1300	A-C	06/07/04	15.711 (39.906)	1.33 (3.38)	1.10 (2.79)	21%	Cross drift trimming
W170, S1445	A-C	06/07/04	8.677 (22.040)	0.76 (1.93)	0.67 (1.70)	13%	Cross drift trimming

in./yr = inch(es) per year.
cm/yr = centimeter(s) per year.
*Chord is defined in "Geotechnical Analysis Report for July 2003–June 2004 Supporting Data."
[a] Increase in convergence rate is calculated from the difference between the 2003–2004 rate and the 2002–2003 rate.

5.4 Excavation Performance

Over 490 readings are collected and assessed on a regular basis from convergence point pairs located throughout the WIPP underground. Convergence rates continue to seasonally vary, typically increasing during the warmer summer months and decreasing during the cooler winter months.

The performance of the access drift excavations during this reporting period was within acceptable criteria. "Acceptable criteria" is when the drift remains accessible and the ground can be controlled by routine maintenance. Standard remedial ground control maintenance in some areas was required to maintain the performance of the excavations. The drifts remain stable and controlled. The majority of the annualized rates remain steady indicating stability. In some locations where the rates are high, nearby mining activities are most likely the cause. In other locations where necessary, additional ground control measures have been or will be installed.

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6.0 Performance of Waste Disposal Area

The Waste Disposal Area as of June 30, 2004, consists of Panels 1, 2 and 3. Panel 1 is closed. Panel 2 is currently being used for waste disposal, with Rooms 5, 6 and 7 filled. Panel 3 mining is complete as shown in Figure 1-2.

Excavation of the Panel 1 waste disposal area began in May 1986 with the mining of access entries to Panel 1. Initially, the disposal rooms and drifts were developed as pilot drifts that were later excavated to nominal operational dimensions of 13 ft (4 m) high, 33 ft (10 m) wide, and 300 ft (91 m) long. Room 1 was completed to these dimensions in August 1986, and pilot drifts for Rooms 2 and 3 were excavated in January and February 1987. Rooms 2 and 3 were completed in February and March 1988 and Rooms 4 through 7 were completed in May 1988. Short access drifts designed to lead to smaller test alcoves were excavated north off of the S1600 drift in June 1989. Only the access drifts to the alcoves were completed; the alcoves were not excavated. Panel 1 waste emplacement is complete and the panel is closed to all access. The Panel 1 access entries, S1600 and S1950 which extend from the E300 drift to the isolation walls, remain open and the instrumentation in this area will continue to be replaced and monitored.

Excavation of the Panel 2 waste disposal area began in September 1999 with the mining of access entries to Panel 2. Initially, the disposal rooms and drifts were developed as pilot drifts that were trimmed to finished dimensions. Room 1 was completed in January 2000, and pilot drifts for Rooms 2 and 3 were excavated in February 2000. Pilot drifts were completed for Rooms 4 through 6 in April 2000. The pilot drift for Room 7 was excavated in May 2000. All the rooms were excavated to final dimensions by August 2000.

Excavation of Panel 3 waste disposal rooms began in May 2002 with the mining of access entries to Panel 3. As with Panel 2, initially, the disposal rooms and drifts were developed as pilot drifts that were trimmed to finished dimensions. All the rooms were excavated to final dimensions by the end of March 2004.

6.1 Modifications to Excavations and Ground Control Activities

There were no new excavations mined in Panel 2 during the reporting period. In Panel 3, initial mining was completed in Rooms 2, 3, 4, 5, 6 and 7, and in the access drifts, S2750 and S3080, from Room 5 to Room 7. Final mining of the entire panel was complete by the end of March 2004. Routine maintenance and ground control activities in the form of trimming, scaling, rock bolt replacement, and installing wire mesh were performed on ribs, floor, and roof throughout accessible areas in Panels 2 and 3. During this reporting period, Panel 2, Rooms 6, 7, parts of South 2520 and South 3080 were wire meshed and bolted. Also during this reporting period, roof bolting was performed in all of the Panel 3 rooms and entries. Table 6-1 summarizes the ground control activities performed in Panels 1, 2 and 3 during this reporting period.

6.2 Instrumentation

Because of Panel 2 floor trimming, there were three convergence points replaced in Room 2 and one convergence point replaced in South 2520 at the intersection of Room 2, Panel 2 during this reporting period. Tables 6-2, 6-3, and 6-4 list the convergence points replaced in Panel 1 entries and Panels 2 and 3. Figures 6-1, 6-2 and 6-3 show the location of the various types of geotechnical instruments in the Panel 1 entries and Panels 2 and 3 of the Waste Disposal Area during this reporting period.

Table 6-1 Summary of Modifications and Ground Control Activities in the Waste Disposal Area from July 1, 2003, to June 30, 2004

Location	Work Performed
Panel 1 entries, S1600 and S1950	installed isolation walls
Panel 2, Rooms 1 through 6, S2180 and S2520	trimmed floor
Panel 3, Rooms 2, 3, 4, 5, 6, and 7	initial mining complete
Panel 3, S2750 and S3080 from Rooms 5 to 7	initial mining complete
Panel 3, All Areas	final mining complete bolting complete

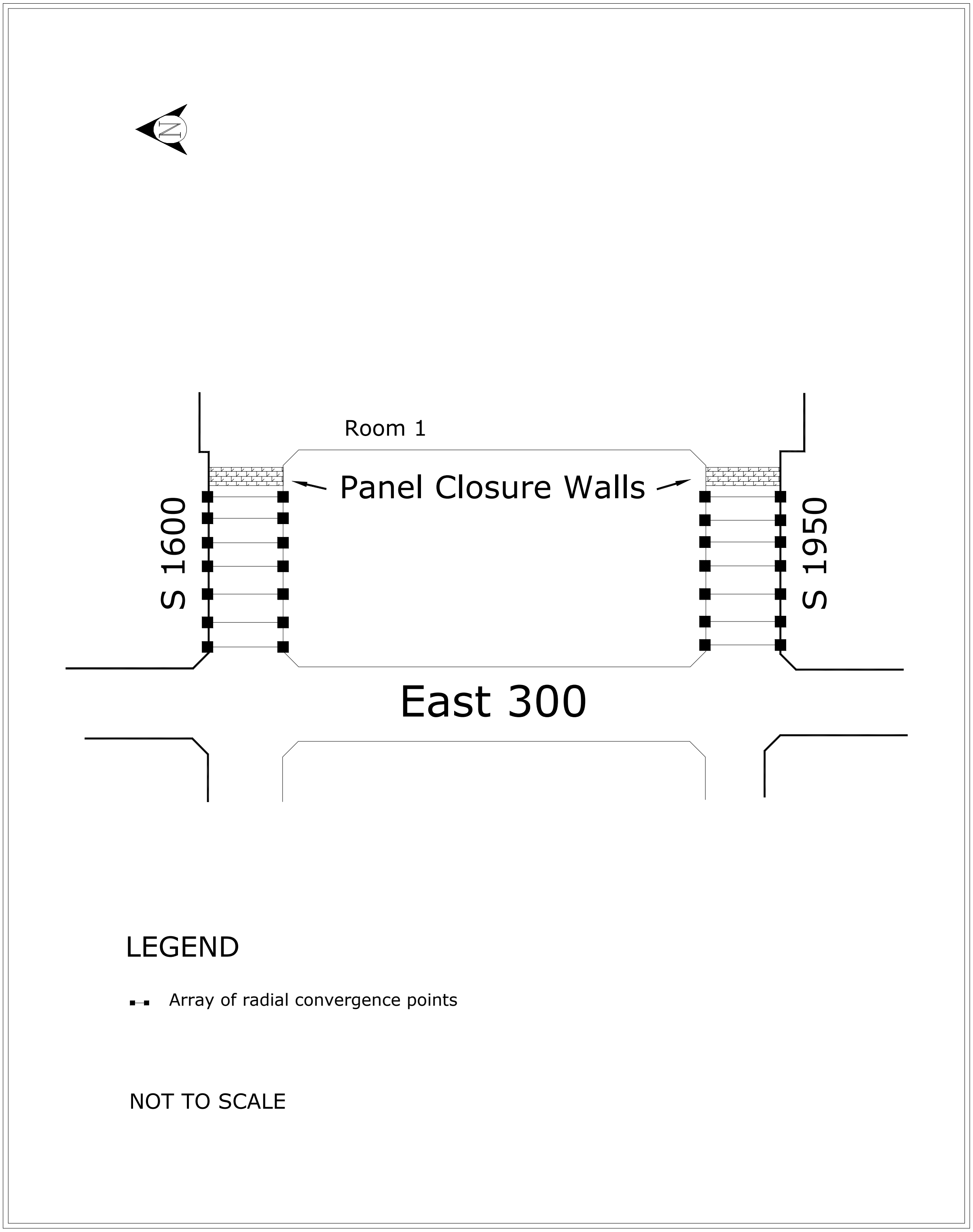

Figure 6-1 Location of Panel 1 Entry Geotechnical Instruments

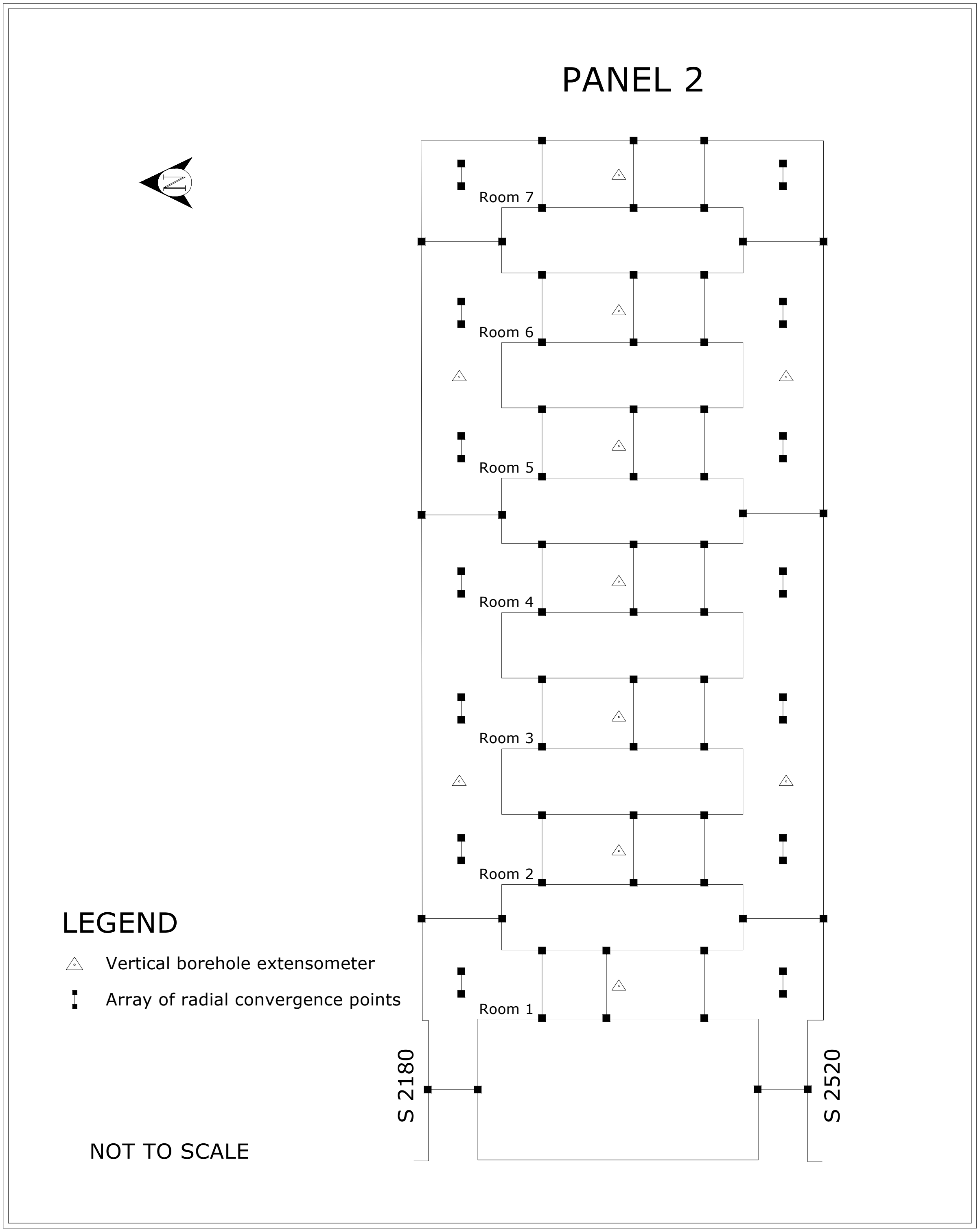

Figure 6-2 Location of Panel 2 Geotechnical Instruments

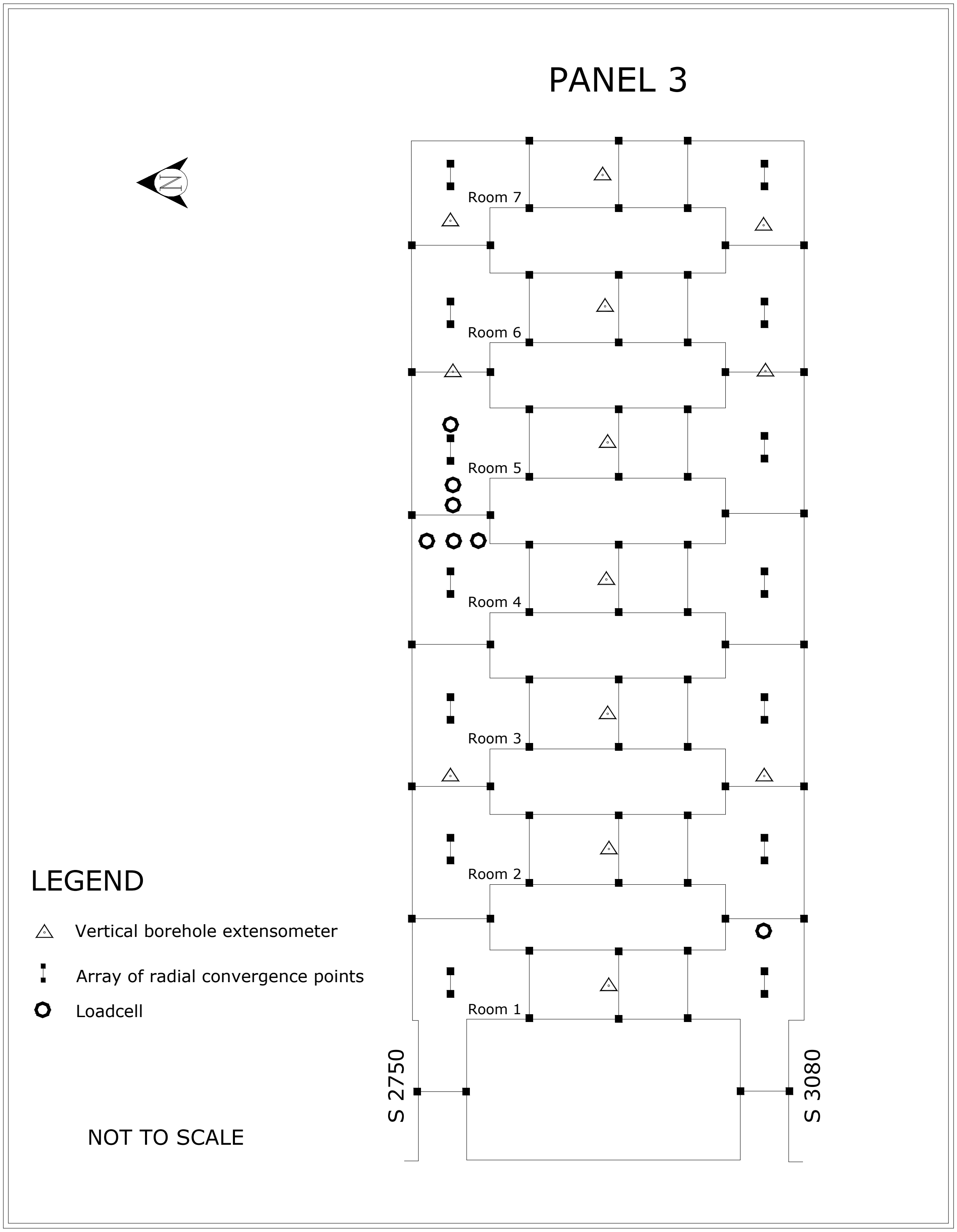

Figure 6-3 Location of Panel 3 Geotechnical Instruments

Table 6-2 New and Replaced Convergence Points in the Panel 1 Entries from July 1, 2003, to June 30, 2004

Location	N/R	Field Tag#	Chord*	Date Installed
S1600, E453	N	S1600-E453	A-C (Vertical)	7/23/2003
S1600, E453	N	S1600-E453	B-D (Horizontal)	7/23/2003
S1950, E311	R	S1950-E311-6	A-C (Vertical)	10/16/2003
S1950, E457	R	S1950-E457-5	A-C (Vertical)	7/23/2003

N = New installation.
R = Replacement installation (i.e., instrument replaces older instrument that has failed or has been mined out).
#Field tag chords are defined in "Geotechnical Analysis Report for July 2003–June 2004 Supporting Data."
*Chord configuration is defined in "Geotechnical Analysis Report for July 2003–June 2004 Supporting Data" and Figure 5-1.

Table 6-3 New and Replaced Convergence Points in Panel 2 from July 1, 2003, to June 30, 2004

Location	N/R	Field Tag#	Chord*	Date Installed
E520, S2275	R	E520-S2275-2	A-C (Vertical)	12/17/2003
E520, S2350	R	E520-S2350-3	A-C (Vertical)	12/17/2003
E520, S2425	R	E520-S2425-2	A-C (Vertical)	12/17/2003
E790, S2275	R	E790-S2275-2	A-C (Vertical)	12/17/2003
E790, S2350	R	E790-S2350-3	A-C (Vertical)	12/17/2003
E790, S2425	R	E790-S2425-2	A-C (Vertical)	12/17/2003
E920, S2275	R	E920-S2275-2	A-C (Vertical)	1/7/2004
E920, S2350	R	E920-S2350-3	A-C (Vertical)	1/7/2004
E920, S2425	R	E920-S2425-2	A-C (Vertical)	1/7/2004
E1050, S2350	R	E1050-S2350-3	A-C (Vertical)	10/22/2003
E1050, S2425	R	E1050-S2425-2	A-C (Vertical)	10/22/2003
S2180, E410	R	S2180-E410-2	A-C (Vertical)	3/18/2004
S2180, E520	R	S2180-E520-2	A-C (Vertical)	3/18/2004
S2180, E586	R	S2180-E586-2	A-C (Vertical)	3/18/2004
S2180, E660	R	S2180-E660-2	A-C (Vertical)	3/18/2004
S2520, E410	R	S2520-E410-3	A-C (Vertical)	1/7/2004
S2520, E520	R	S2520-E520-3	A-C (Vertical)	1/7/2004
S2520, E586	R	S2520-E586-2	A-C (Vertical)	1/7/2004
S2520, E660	R	S2520-E660-3	A-C (Vertical)	12/17/2003
S2520, E790	R	S2520-E790-2	A-C (Vertical)	12/17/2003
S2520, E920	R	S2520-E920-2	A-C (Vertical)	1/7/2004
S2520, E985	R	S2520-E985-2	A-C (Vertical)	1/7/2004
S2520, E1050	R	S2520-E1050-2	A-C (Vertical)	10/22/2003

N = New installation.
R = Replacement installation (i.e., instrument replaces older instrument that has failed or has been mined out).
#Field tag chords are defined in "Geotechnical Analysis Report for July 2003–June 2004 Supporting Data."
*Chord configuration is defined in "Geotechnical Analysis Report for July 2003–June 2004 Supporting Data" and Figure 5-1.

Table 6-4 New and Replaced Convergence Points in Panel 3 from July 1, 2003, to June 30, 2004

Location	N/R	Field Tag#	Chord*	Date Installed
E520, S2833	N	E520-S2833	A-C (Vertical)	7/15/2003
E520, S2833	N	E520-S2833	B-D (Horizontal)	7/15/2003
E520, S2833	R	E520-S2833-2	A-C (Vertical)	6/21/2004
E520, S2916	N	E520-S2916	A-C (Vertical)	7/11/2003
E520, S2916	N	E520-S2916	B-D (Horizontal)	7/15/2003
E520, S2916	R	E520-S2916-2	A-C (Vertical)	6/21/2004
E520, S2998	N	E520-S2998	A-C (Vertical)	7/15/2003
E520, S2998	N	E520-S2998	B-D (Horizontal)	4/16/2004
E520, S2998	R	E520-S2998-2	A-C (Vertical)	6/21/2004
E660, S2833	N	E660-S2833	A-C (Vertical)	8/8/2003
E660, S2833	R	E660-S2833-2	A-C (Vertical)	4/16/2004
E660, S2916	N	E660-S2916	A-C (Vertical)	8/8/2003
E660, S2916	N	E660-S2916	B-D (Horizontal)	4/16/2004
E660, S2916	R	E660-S2916-2	A-C (Vertical)	4/16/2004
E660, S2998	N	E660-S2998	A-C (Vertical)	8/8/2003
E660, S2998	N	E660-S2998	B-D (Horizontal)	4/16/2004
E660, S2998	R	E660-S2998-2	A-C (Vertical)	4/16/2004
E790, S2833	N	E790-S2833	A-C (Vertical)	8/21/2003
E790, S2833	N	E790-S2833	B-D (Horizontal)	4/16/2004
E790, S2833	R	E790-S2833-2	A-C (Vertical)	4/16/2004
E790, S2916	N	E790-S2916	A-E (Vertical)	8/8/2003
E790, S2916	N	E790-S2916	B-D (Horizontal)	8/21/2003
E790, S2916	N	E790-S2916	C-G (Horizontal)	3/5/2004
E790, S2916	N	E790-S2916	F-H (Vertical)	8/21/2003
E790, S2916	R	E790-S2916-2	A-E (Vertical)	4/16/2004
E790, S2998	N	E790-S2998	A-C (Vertical)	9/4/2003
E790, S2998	N	E790-S2998	B-D (Horizontal)	3/5/2004
E790, S2998	R	E790-S2998-2	A-C (Vertical)	4/16/2004
E920, S2833	N	E920-S2833	A-C (Vertical)	9/4/2003
E920, S2833	N	E920-S2833	B-D (Horizontal)	4/22/2004
E920, S2833	R	E920-S2833-2	A-C (Vertical)	4/22/2004
E920, S2916	N	E920-S2916	A-C (Vertical)	9/4/2003
E920, S2916	N	E920-S2916	B-D (Horizontal)	4/22/2004
E920, S2916	R	E920-S2916-2	A-C (Vertical)	4/22/2004
E920, S2998	N	E920-S2998	A-C (Vertical)	9/4/2003
E920, S2998	N	E920-S2998	B-D (Horizontal)	4/22/2004
E920, S2998	R	E920-S2998-2	A-C (Vertical)	4/22/2004
E1050, S2833	N	E1050-S2833	A-C (Vertical)	6/17/2004
E1050, S2833	N	E1050-S2833	B-D (Horizontal)	3/5/2004
E1050, S2916	N	E1050-S2916	A-C (Vertical)	1/6/2004
E1050, S2916	N	E1050-S2916	B-D (Horizontal)	3/5/2004
E1050, S2916	R	E1050-S2916-2	A-C (Vertical)	6/17/2004

Table 6-4 Continued

Location	N/R	Field Tag#	Chord*	Date Installed
E1050, S2998	N	E1050-S2998	A-C (Vertical)	6/17/2004
E1050, S2998	N	E1050-S2998	B-D (Horizontal)	3/5/2004
E1190, S2833	N	E1190-S2833	A-C (Vertical)	6/10/2004
E1190, S2833	N	E1190-S2833	B-D (Horizontal)	2/6/2004
E1190, S2916	N	E1190-S2916	A-C (Vertical)	1/6/2004
E1190, S2916	N	E1190-S2916	B-D (Horizontal)	2/6/2004
E1190, S2916	R	E1190-S2916-2	A-C (Vertical)	6/11/2004
E1190, S2998	N	E1190-S2998	A-C (Vertical)	6/11/2004
E1190, S2998	N	E1190-S2998	B-D (Horizontal)	2/6/2004
E1320, E2916	N	E1320-S2916	B-D (Horizontal)	2/6/2004
E1320, S2833	N	E1320-S2833	A-C (Vertical)	6/11/2004
E1320, S2833	N	E1320-S2833	B-D (Horizontal)	2/6/2004
E1320, S2916	N	E1320-S2916	A-C (Vertical)	1/6/2004
E1320, S2916	R	E1320-S2916-2	A-C (Vertical)	6/11/2004
E1320, S2998	N	E1320-S2998	A-C (Vertical)	6/11/2004
E1320, S2998	N	E1320-S2998	B-D (Horizontal)	2/6/2004
S2750, E410	N	S2750-E410	A-C (Vertical)	7/14/2003
S2750, E410	N	S2750-E410	B-D (Horizontal)	7/14/2003
S2750, E520	N	S2750-E520	A-C (Vertical)	11/5/2003
S2750, E520	R	S2750-E520-2	A-C (Vertical)	6/25/2004
S2750, E586	N	S2750-E586	A-C (Vertical)	11/5/2003
S2750, E586	R	S2750-E586-2	A-C (Vertical)	6/25/2004
S2750, E660	N	S2750-E660	A-C (Vertical)	11/5/2003
S2750, E660	R	S2750-E660-2	A-C (Vertical)	6/25/2004
S2750, E790	N	S2750-E790	A-C (Vertical)	11/5/2003
S2750, E790	R	S2750-E790-2	A-C (Vertical)	6/25/2004
S2750, E920	N	S2750-E920	A-C (Vertical)	11/5/2003
S2750, E920	R	S2750-E920-2	A-C (Vertical)	6/25/2004
S2750, E986	N	S2750-E986	A-C (Vertical)	11/5/2003
S2750, E986	R	S2750-E986-2	A-C (Vertical)	6/25/2004
S2750, E1050	N	S2750-E1050	A-C (Vertical)	11/5/2003
S2750, E1050	R	S2750-E1050-2	A-C (Vertical)	6/25/2004
S2750, E1190	N	S2750-E1190	A-C (Vertical)	1/6/2004
S2750, E1190	R	S2750-E1190-2	A-C (Vertical)	1/28/2004
S2750, E1190	R	S2750-E1190-3	A-C (Vertical)	6/25/2004
S2750, E1255	N	S2750-E1255	A-C (Vertical)	1/6/2004
S2750, E1255	R	S2750-E1255-2	A-C (Vertical)	6/25/2004
S2750, E1320	N	S2750-E1320	A-C (Vertical)	1/6/2004
S2750, E1320	R	S2750-E1320-2	A-C (Vertical)	6/25/2004
S3080, E410	N	S3080-E410	A-C (Vertical)	7/11/2003
S3080, E410	N	S3080-E410	B-D (Horizontal)	7/11/2003
S3080, E520	N	S3080-E520	A-C (Vertical)	9/8/2003

Table 6-4 Continued

Location	N/R	Field Tag#	Chord*	Date Installed
S3080, E520	R	S3080-E520-2	A-C (Vertical)	6/25/2004
S3080, E586	N	S3080-E586	A-C (Vertical)	9/8/2003
S3080, E586	N	S3080-E586	B-D (Horizontal)	6/17/2004
S3080, E586	R	S3080-E586-2	A-C (Vertical)	6/17/2004
S3080, E660	N	S3080-E660	A-C (Vertical)	9/8/2003
S3080, 660	R	S3080-E660-2	A-C (Vertical)	6/17/2004
S3080, E725	N	S3080-E725	A-C (Vertical)	6/30/2004
S3080, E725	N	S3080-E725	B-D (Horizontal)	6/30/2004
S3080, E790	N	S3080-E790	A-C (Vertical)	9/4/2003
S3080, E790	R	S3080-E790-2	A-C (Vertical)	6/17/2004
S3080, E857	N	S3080-E857	A-C (Vertical)	9/4/2003
S3080, E857	N	S3080-E857	B-D (Horizontal)	6/30/2004
S3080, E857	R	S3080-E857-2	A-C (Vertical)	6/30/2004
S3080, E920	N	S3080-E920	A-C (Vertical)	9/4/2003
S3080, E920	R	S3080-E920-2	A-C (Vertical)	6/25/2004
S3080, E986	N	S3080-E986	A-C (Vertical)	1/15/2004
S3080, E986	N	S3080-E986	B-D (Horizontal)	6/30/2004
S3080, E986	R	S3080-E986-2	A-C (Vertical)	6/30/2004
S3080, E1050	N	S3080-E1050	A-C (Vertical)	1/6/2004
S3080, E1050	R	S3080-E1050-2	A-C (Vertical)	6/17/2004
S3080, E1190	N	S3080-E1190	A-C (Vertical)	1/6/2004
S3080, E1255	N	S3080-E1255	A-C (Vertical)	1/6/2004
S3080, E1255	N	S3080-E1255	B-D (Horizontal)	2/6/2004
S3080, E1255	R	S3080-E1255-2	A-C (Vertical)	6/17/2004
S3080, E1320	N	S3080-E1320	A-C (Vertical)	1/6/2004
S3080, E1320	R	S3080-E1320-2	A-C (Vertical)	6/11/2004

N = New installation.
R = Replacement installation (i.e., instrument replaces older instrument that has failed or has been mined out).
#Field tag chords are defined in "Geotechnical Analysis Report for July 2003–June 2004 Supporting Data."
*Chord configuration is defined in "Geotechnical Analysis Report for July 2003–June 2004 Supporting Data." and Figure 5-1.

6.3 Excavation Performance

Horizontal and vertical convergence rates have been calculated for the S1600 and S1950 entries of Panel 1 for this and the previous reporting period. Tables 6-5 and 6-6 present these convergence rates. The vertical and horizontal convergence rates in the Panel entries have all increased with the exception of the South 1950, East 457 horizontal convergence point.

Table 6-5 Annual Convergence Rates in the S1600 Panel 1 Entry

Location	Chord*	Last Reading	Total Cumulative Displacement Inches/(cm.)	Closure Rate 2003 to 2004 in./yr (cm/yr)	Closure Rate 2002 to 2003 in./yr (cm/yr)	Rate Change Percent [a]	Comments
S1600, E311	A-C (Vertical)	06/25/04	16.011 (40.668)	0.79 (2.00)	0.77 (1.94)	3%	
S1600, E311	B-D (Horizontal)	06/25/04	14.387 (36.543)	0.72 (1.82)	0.60 (1.51)	21%	
S1600, E332	A-C (Vertical)	06/25/04	13.908 (35.326)	0.84 (2.12)	0.68 (1.72)	24%	
S1600, E357	A-C (Vertical)	06/25/04	16.260 (41.300)	0.96 (2.44)	0.75 (1.89)	29%	
S1600, E382	A-C (Vertical)	06/25/04	16.365 (41.567)	0.94 (2.39)	0.72 (1.83)	30%	
S1600, E407	A-G (Vertical)	06/25/04	17.215 (43.726)	1.02 (2.58)	0.74 (1.88)	38%	
S1600, E407	B-F (Vertical)	06/25/04	15.815 (40.170)	0.95 (2.42)	0.68 (1.74)	39%	
S1600, E407	H-L (Vertical)	06/25/04	16.515 (41.948)	1.00 (2.55)	0.76 (1.92)	33%	
S1600, E432	A-C (Vertical)	06/25/04	20.302 (51.567)	1.11 (2.81)	0.93 (2.36)	19%	

in./yr = inch(es) per year.
cm/yr = centimeter(s) per year.
*Chord is defined in "Geotechnical Analysis Report for July 2003–June 2004 Supporting Data" and Figure 5-1
[a] Increase in convergence rate is calculated from the difference between the 2003–2004 rate and the 2002–2003 rate.

Table 6-6 Annual Convergence Rates in the S1950 Panel 1 Entry

Location	Chord*	Last Reading	Total Cumulative Displacement Inches/(cm.)	Closure Rate 2003 to 2004 in./yr (cm/yr)	Closure Rate 2002 to 2003 in./yr (cm/yr)	Rate Change Percent [a]	Comments
S1950, E311	B-D (Horizontal)	06/29/04	20.205 (51.321)	1.12 (2.85)	0.87 (2.20)	30%	
S1950, E332	A-C (Vertical)	06/29/04	27.099 (68.831)	1.41 (3.58)	1.28 (3.25)	10%	
S1950, E332	B-D (Horizontal)	06/29/04	22.395 (56.883)	1.23 (3.12)	0.98 (2.50)	25%	
S1950, E357	B-D (Horizontal)	06/29/04	23.243 (59.037)	1.31 (3.34)	1.14 (2.90)	15%	
S1950, E357	A-C (Vertical)	06/29/04	30.832 (78.313)	1.74 (4.42)	1.60 (4.06)	9%	
S1950, E382	B-D (Horizontal)	06/29/04	25.197 (64.000)	1.40 (3.55)	1.21 (3.07)	16%	
S1950, E382	A-C (Vertical)	06/29/04	31.439 (79.855)	1.98 (5.02)	1.74 (4.42)	14%	
S1950, E407	C-K (Horizontal)	04/27/04	23.157 (58.819)	1.30 (3.29)	1.21 (3.07)	7%	
S1950, E407	D-J (Horizontal)	06/29/04	25.654 (65.161)	1.48 (3.77)	1.34 (3.39)	11%	
S1950, E407	H-L (Vertical)	06/29/04	34.399 (87.373)	2.15 (5.47)	1.80 (4.56)	20%	
S1950, E407	A-G (Vertical)	06/29/04	34.057 (86.505)	2.12 (5.39)	1.95 (4.96)	9%	
S1950, E432	A-C (Vertical)	06/29/04	34.410 (87.401)	2.04 (5.18)	2.00 (5.09)	2%	
S1950, E432	B-D (Horizontal)	06/29/04	25.317 (64.305)	1.41 (3.58)	1.26 (3.19)	12%	
S1950, E457	B-D (Horizontal)	06/29/04	24.876 (63.185)	0.63 (1.61)	1.18 (2.99)	-46%	

in./yr = inch(es) per year.
cm/yr = centimeter(s) per year.
*Chord is defined in "Geotechnical Analysis Report for July 2003–June 2004 Supporting Data." & Figure 5-1
[a] Increase in convergence rate is calculated from the difference between the 2003–2004 rate and the 2002–2003 rate.

Horizontal and vertical convergence rates have been calculated at the center of each of the rooms in Panel 2 for this and the previous reporting period. Tables 6-7 and 6-8 present these convergence rates. The vertical and horizontal convergence rates at the center of each room in Panel 2 have all increased with the exception of the Room 6 horizontal center point.

Table 6-7 Annual Vertical Convergence Rates at the Center of Panel 2 Rooms

Location	Chord*	Last Reading	Total Cumulative Displacement Inches/(cm.)	Closure Rate 2003 to 2004 in./yr (cm/yr)	Closure Rate 2002 to 2003 in./yr (cm/yr)	Rate Change Percent	Comments
Room 1, E520, S2350	A-C	06/29/04	17.567 (44.620)	4.74 (12.04)	3.38 (8.60)	40%	Floor Trimming
Room 2, E660, S2350	A-C	06/29/04	17.512 (44.480)	3.96 (10.07)	3.31 (8.40)	20%	Floor Trimming
Room 3, E790, S2350	A-C	06/07/04	15.691 (39.855)	3.72 (9.44)	2.92 (7.42)	27%	Floor Trimming
Room 4, E920, S2350	A-C	04/20/04	17.811 (45.240)	3.64 (9.26)	3.20 (8.12)	14%	Floor Trimming
Room 5, E1050, S2350	A-C	09/23/03	15.825 (40.196)	3.22 (8.18)	2.92 (7.42)	10%	Floor Trimming
Room 6, E1190, S2350	A-C	08/26/03	14.041 (35.664)	2.99 (7.59)	2.87 (7.29)	4%	
Room 7[b] ,E1320, S2350	A-C	N/A	N/A	N/A	N/A	N/A	

in./yr = inch(es) per year

cm/yr = centimeter(s) per year

*Chord is defined in "Geotechnical Analysis Report for July 2003–June 2004 Supporting Data," and Figure 5-1
[a]Increase in convergence rate is calculated from the difference between the 2003–2004 rate and the 2002–2003 rate.
[b]Panel 2, Room 7 closed during this reporting period.

Table 6-8 Annual Horizontal Convergence Rates at the Center of Panel 2 Rooms (Mid-Rib)

Location	Chord*	Last Reading	Total Cumulative Displacement Inches/(cm.)	Closure Rate 2003 to 2004 in./yr (cm/yr)	Closure Rate 2002 to 2003 in./yr (cm/yr)	Rate Change Percent	Comments
Room 1, E520, S2350	B-D	06/29/04	11.422 (29.012)	2.69 (6.82)	2.29 (5.81)	17%	Floor Trimming
Room 2, E660, S2350	B-D	12/02/03	9.780 (24.841)	2.15 (5.46)	2.10 (5.33)	2%	Floor Trimming
Room 3, E790, S2350	B-D	06/07/04	10.059 (25.550)	2.27 (5.77)	1.99 (5.04)	14%	Floor Trimming
Room 4, E920, S2350	B-D	04/20/04	10.588 (26.894)	2.38 (6.04)	2.08 (5.29)	14%	Floor Trimming
Room 5, E1050, S2350	B-D	10/22/03	8.092 (20.554)	2.26 (5.73)	1.79 (4.53)	26%	Floor Trimming
Room 6, E1190, S2350	B-D	08/26/03	7.511 (19.078)	1.30 (3.31)	1.65 (4.20)	-21%	
Room 7[b] ,E1320, S2350	B-D	N/A	N/A	N/A	N/A	N/A	

in./yr = inch(es) per year

cm/yr = centimeter(s) per year

*Chord is defined in "Geotechnical Analysis Report for July 2003–June 2004 Supporting Data." & Figure 5-1
[a]Increase in convergence rate is calculated from the difference between the 2003–2004 rate and the 2002–2003 rate.
[b]Panel 2, Room 7 closed during this reporting period.

All of Panel 3 was mined as of June 30, 2004. Monitoring data indicates a reduction in the extensometer and convergence rates as a result of initial mining. There is insufficient data for comparison to the previous reporting period.

6.4 Analysis of Extensometer and Convergence Point Data

There were 19 monitored extensometers installed in the roofs of Panels 2 and 3. Eleven of the extensometers are located in Panel 2 and eight are in Panel 3. Most of the extensometers are located in the center of the disposal rooms with the exception of four extensometers located in the Panel 2 ventilation drifts. All of the extensometers in Panel 2 showed a displacement rate increase with the exception of the extensometer located in Panel 2, Room 6, which had an erroneous reading due to the loss of the deepest anchor. The convergence and roof beam expansion rate increases in Panel 2 are probably in response to floor trimming in Rooms 1 through 6 and the effect of mining of Panel 3.

During this reporting period, vertical convergence rates were read in the Panel 1 entries, Panel 2 and Panel 3. Convergence rates from the Panel 1 entries increased, with the exception of one point located at South 1950, East 457 which showed a 46 percent rate decrease. The rate increases in the Panel 1 entries can be attributed to rib and floor trimming conducted in preparation of the panel closure construction. Convergence monitoring nearest the panel closure wall indicate a significant reduction in closure rate since the closure wall was constructed.

The closure rates in Panel 2 increased with exception of one location in Panel 2, Room 5 and two in Panel 2, Rooms 6. At the center convergence point in Room 1, the closure rate increase was the highest at 40 percent. Convergence in South 2520 and the southernmost points in the rooms of Panel 2 were the most affected by the mining of Panel 3. Closure rates in Panel 2 show an indication of decreasing due to redistribution of Panel 3 mining stress.

Convergence data from Panel 3 indicate annualized closure rates varying from 11.41 in/year (28.98 cm/yr) at the center vertical point of Room 6 to 4.63 in/year (11.75 cm/yr) at the north quarter convergence vertical point of Room 5. The initial effects due to mining significantly decreased similar to that experienced in the previous panels. However, subsequent monitoring indicated some areas with increased convergence and roof beam deformation. These areas were associated with the development of separations along thin anhydrite stringers observed in the lower roof beam. The number and continuity of these stringers vary, however, these stringers are commonly observed throughout the panel. Deformation rates, in these areas, have stabilized or decreased in response to installation of ground control.

7.0 Geoscience Program

The Geoscience Program confirms the suitability of the site through the collection of various geologic data and excavation characteristics from the underground facility. These include the inspection of open boreholes for fractures (separations) and offsets (lateral displacements) in roof beams and the mapping of fracture development on roof (back) surfaces.

Data collected through these activities support the design and evaluation of ground support systems (Westinghouse Waste Isolation Division, 1999).

During this reporting period, the following activities were performed:

- Borehole Inspections
- Fracture Mapping

7.1 Borehole Inspections

Geotechnical observation boreholes are drilled at various locations throughout the underground facility. A location may contain one or more boreholes arranged in an array. These holes are drilled to depths that allow the monitoring of fracture development and offsetting and are inspected for the development of those features. Depending on location roof observation holes usually intersect clays "G" and "H" (Figure 7-1) or "H" and "I."

The clay seams nearest the excavation surfaces define the immediate roof beam. The roof beam is bounded by clay "G" in most of the access drifts and Panels 1 and 2. Some areas, such as the Salt Handling Shaft Station, portions of the East 0 and East 140 drifts, the south mains south of South 2620 and Panel 3 are excavated to clay "G" and so have roof beams bounded by clay "H."

The offset in a borehole is determined by visually estimating the degree of borehole occlusion. The direction of offset along clay seams is observed as the movement of the strata nearer to the observer relative to the strata farther away. Typically, the nearer strata move toward the center of the excavation (Figure 7-2). Based on previous observations in the underground, the magnitude of offset is usually greater in boreholes located near ribs than in those located along excavation centerlines. Offsetting along the clay layers is

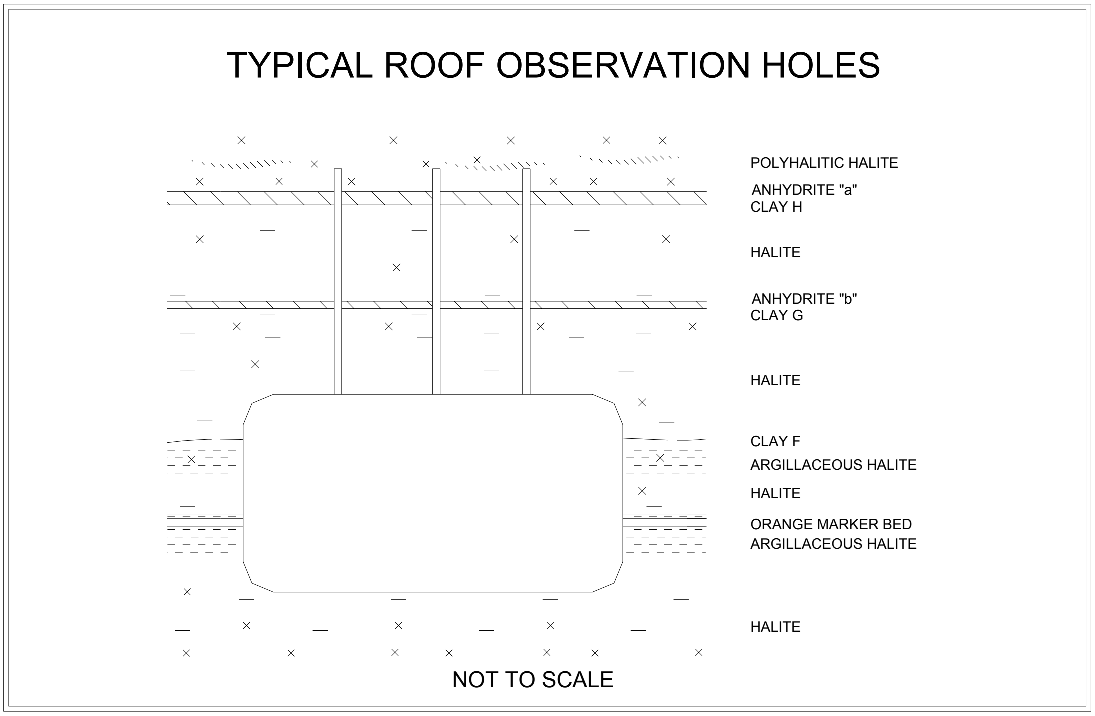

Figure 7-1 Examples of Observation Borehole Layouts

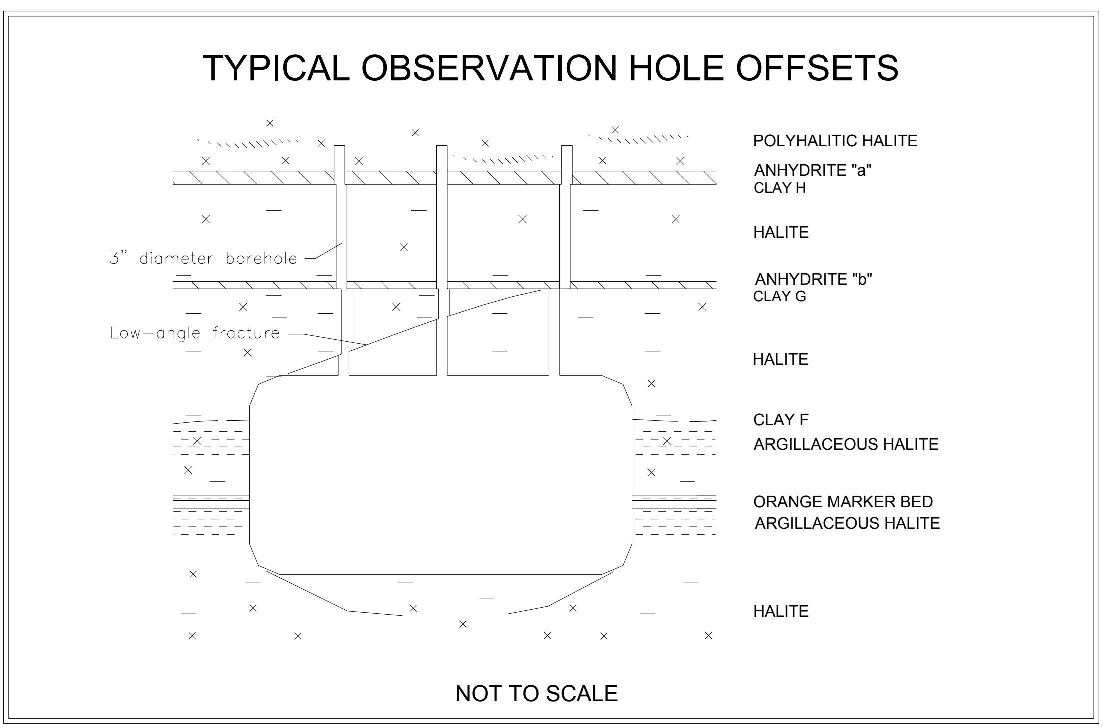

Figure 7-2 Generalized Fracture Pattern at Lower Horizon

observable until the total borehole offset is reached or visibility is obstructed by intervening offsets at other clay seams or fractures. Boreholes are inspected for fractures using an aluminum rod with a flattened steel wire probe attached to one end perpendicular to the rod (referred to as a "scratcher rod"). Fractures and clay seams are located by moving the probe along the inside of the borehole until it is snagged in one of these features. Depth to each feature is recorded, as is the magnitude of separations encountered. In addition, during this reporting period, a use of the borehole camera has been introduced in conjunction with the scratch rod.

The separation and offset data observed in accessible boreholes during this reporting period are presented in the supporting data document for this report.[6] Twenty-eight of the 45 observation holes in Panel 3 show some offset. Most offsets are minor, with the exception of six of the 11 holes in South 2750 which range from 33 to 42 percent closure. Only one hole in South 3080 exhibits closure of greater than 33 percent.

7.2 Fracture Mapping

Routine mapping documents the progression of fractures in the roof exposed on the excavation surfaces of the drifts and rooms in the underground repository. The fracture surveys are generally performed on an annual basis, and the fracture maps are updated. The fracture maps facilitate the analysis of strain in the immediate roof-beam as they document the development and propagation of fractures through time. The supporting data document contains fracture maps for Panels 2 and 3. For this reporting period, Rooms 1 through 4 and a limited portion of South 2180 and South 2750 were accessible in Panel 2.

[6] Instrumentation data and data plots are available in "Geotechnical Analysis Report for July 2002-June 2003 Supporting Data." This document is available upon request from Washington TRU Solutions. Refer to Foreword and Acknowledgments for details and address.

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8.0 Summary

At the inception of the WIPP Project, criteria were developed that address the requirements for the design of WIPP (DOE, 1984). These criteria, in the form of design requirements, pertain to all aspects of the mined facility and its operation as a pilot plant for the demonstration of technical and operational methods for permanent disposal of contact-handled (CH) and remote-handled (RH) TRU waste. In 1994, as WIPP developed and the focus moved toward the permanent disposal of TRU waste, these design requirements were reassessed and replaced by a new set of requirements called system design descriptions (SDDs). Table 8-1 shows the comparison of these design requirements with conditions actually observed in the underground from July 2003 through June 2004.

Fracture development in the roof is primarily caused by the concentration of compressive stresses in the roof beam and is influenced by the size and shape of the excavation and the stratigraphy in the immediate vicinity of the opening. In a thick roof beam, pillar deformations induce lateral compressive stresses into the immediate roof and floor. With time, the buildup of stress causes differential movement along stratigraphic boundaries. This differential movement is identified as offsets in observation boreholes and is indicated by the bends in failed rock bolts. Large strains associated with lateral movements can induce fracturing in the roof, which is frequently seen near the ribs, however, this process may take a long time (years) to develop.

At some locations, such as Panel 3 where anhydrite stringers occur in the roof, clay or anhydrite stringers can dominate the effective thickness of the roof beam. The presence of these stringers causes the roof beam to behave as a series of thin independent beams. There is little or no tensile support provided across the stringer interface. As horizontal end loading continues, each beam can deflect downward causing a tensile fracture to develop along the bottom of the beam. These tensile fractures can develop in relatively new excavations soon after separation occurs along the stringer interface.

The location and initiation of interface separation is also influenced by slope of the stratigraphic beds. Currently the roofs and floors of the excavation are mined level through the sloping beds. At some locations, this may be the result the result of a significant differential roof beam thickness from one side of the excavation to the other. Areas with the thinnest beam are the most likely to separate and subsequently develop fracturing.

Normal drift and room maintenance continued during this reporting period with rib, roof, and floor scaling and trimming in various locations, and rock bolts and wire mesh installed as needed. Supplemental ground control systems consisting of resin anchored bolts and roof mats were installed in sections of the E140 drift, Panel 3 and the Waste Shaft Station.

New geomechanical instrumentation was installed in Panel 3 and the Panel 3 access drifts and in various locations throughout the repository to replace mined-out instruments. Remote convergence monitoring no longer continues in non-accessible areas in the north. All accessible areas of the underground are connected to data loggers or are monitored manually.

The *in situ* performance of the excavations generally continues to satisfy the appropriate design criteria, although specific areas are being identified where deterioration resulting from aging must be addressed through routine maintenance and implementation of engineered systems. This deterioration has been identified through the analysis of data acquired from geomechanical instrumentation and the Geoscience Program. If the planned life of some of the openings needs to be extended, redesigning the geometry of the access drifts (e.g., changing the horizontal and vertical dimensions) or additional ground control (e.g., roof removal, installing bolts, mesh, or straps) may be necessary. The ground conditions in the Waste Disposal Area and associated waste transport routes continue to slowly deteriorate; however, routine ground control installations and maintenance continue to allow safe access in the underground facility.

In addition to underground instrumentation, qualitative assessments of fracture development are documented through mapping the underground repository and inspecting the observation boreholes. The information acquired from these programs provides early detection of ground deterioration, contributes to the understanding of the dynamic geomechanical processes in the WIPP underground, and aids in the design of effective ground control and support systems.

Table 8-1 Comparison of Excavation Performance to System Design Requirements

Requirement	Comments
"The lining shall be designed for a hydrostatic pressure. . . ."	Water pressure observed on piezometers located behind the shaft liners remains below design levels.
"The key shall be designed to resist the lateral pressure generated by salt creep."	Geomechanical data from the Waste Shaft indicate that the shaft key is minimally loaded and is structurally stable. Visual inspections of all shaft keys do not indicate any deterioration due to creep loading.
"The key shall be designed to retain the rock formation and will be provided with chemical seal rings and a water collection ring with drains to prevent water from flowing down the unlined shaft from the lining above."	Shaft inspection observations and instrumentation show no indication of instability due to salt dissolution.
"The underground waste disposal facilities shall be designed to provide space and adequate access for the underground equipment and temporary storage space to support underground operations."	Geomechanical instrument data and visual observations indicate that the current design provides adequate access and storage space. Ground control maintenance is performed as necessary to maintain access.
"Entries and sub-entries to the underground disposal area and the experimental areas shall be provided and sized for personnel safety, adequate air flow, and space for equipment."	Deformation of excavation remains within the required limits. Normal periodic maintenance consisting of rock bolting, wire meshing, trimming, and scaling continue throughout the repository. All of the Northeast and Northwest Areas, a former experimental area, is now deactivated and closed to access.
"Geomechanical instrumentation shall be provided to measure the cumulative deformation of the rock mass surrounding mined drifts. . . ."	Geotechnical instrumentation is operated and maintained to meet this requirement. This annual report acts to provide a summary and analysis of the geomechanical data.

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